SCIENTIFIC AMERICAN
No. SUPPLEMENT 721

Scientific American Supplement, Vol. XXVIII. No. 721.
Scientific American, established 1845.

NEW YORK, OCTOBER 26, 1889.

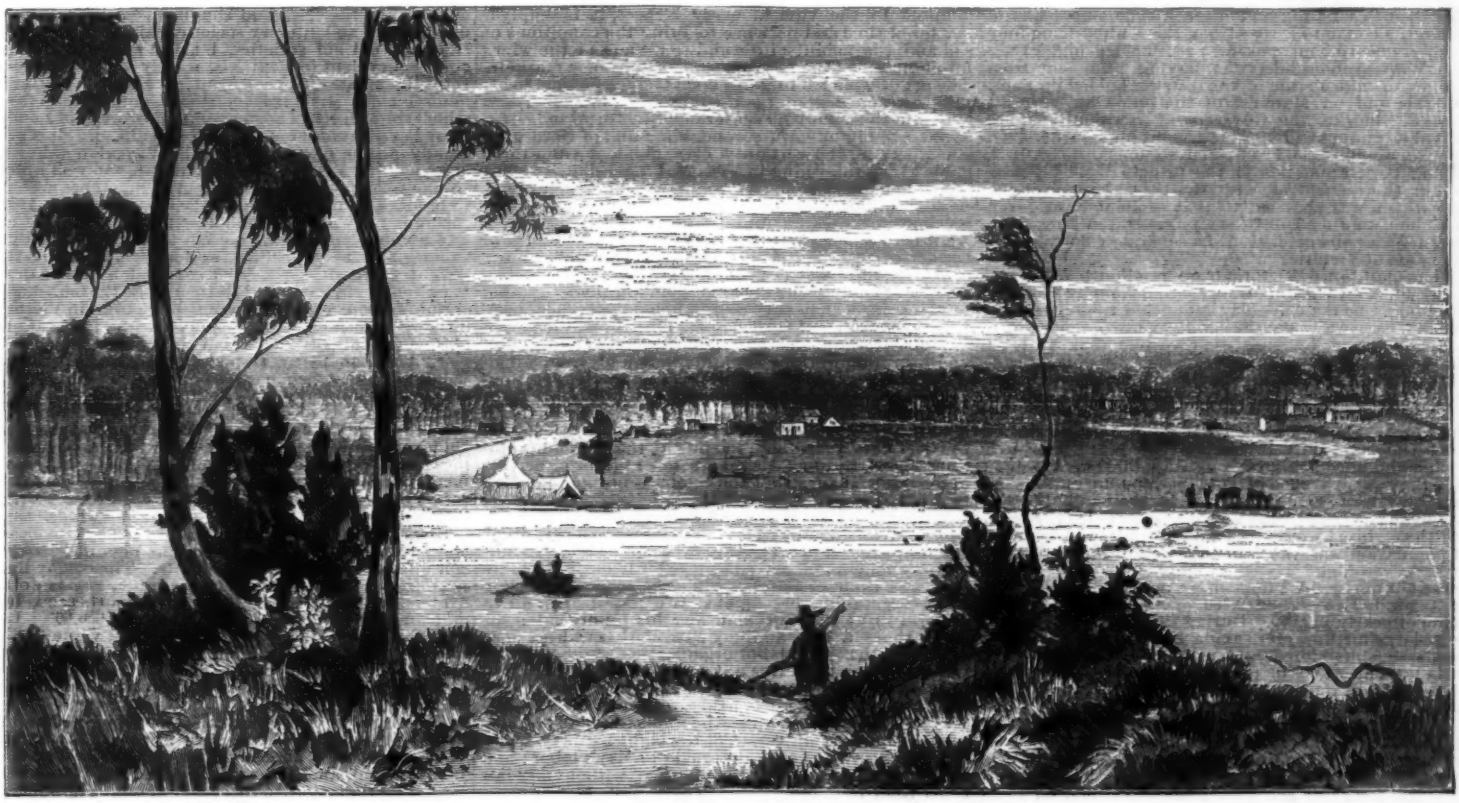
Scientific American Supplement, $5 a year.
Scientific American and Supplement, $7 a year.

THE COLONY OF VICTORIA.

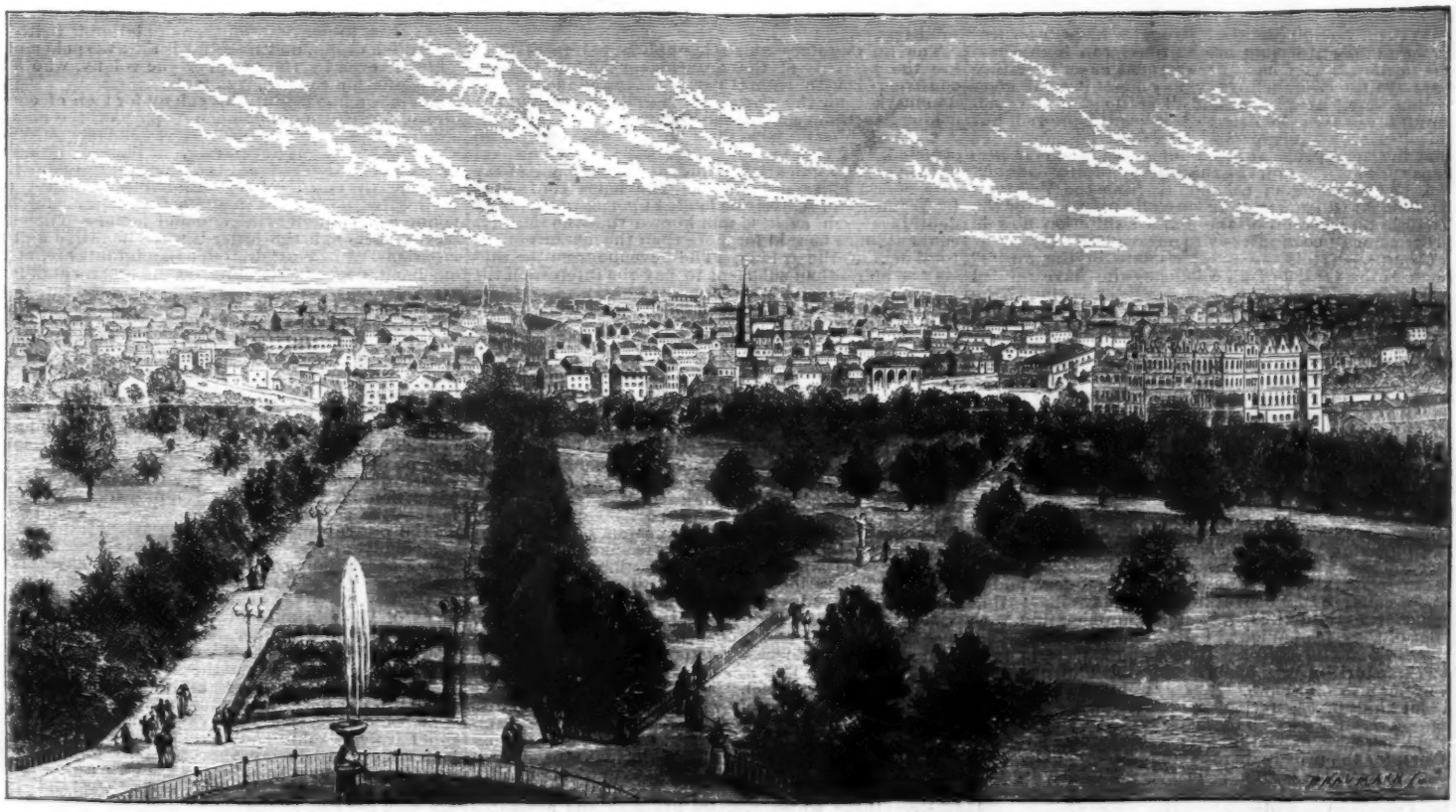
THE colony of Victoria occupies the southeastern portion of the Australian continent, and extends from the 34th to the 39th degree of latitude and from the 101st to the 150th degree of longitude. Its superficial area is 87,884 square miles, somewhat less than that of Great Britain; its extreme length being 480 miles from east to west, and its breadth from north to south 240 miles. It is bordered to the north and northeast by the colony of New South Wales, from which it is separated by the river Murray; to the west it is bounded by the colony of South Australia; to the south and southeast, its shores are those of the Indian Ocean, Bass's Strait, and the Pacific Ocean.

Attempts had been made to colonize this portion of the Australian continent so far back as 1803; but the first permanent settlement in Victoria was formed at Portland Bay in 1834, when Mr. Edward Henty landed from the neighboring colony of Tasmania (Van Diemen's Land, as it was then called), and soon began to till the soil, run and breed stock, and carry on whaling operations.

Others followed, but the absence of good land in the



MELBOURNE IN 1837.



MELBOURNE IN 1889—VIEW LOOKING SOUTH.

THE COLONY OF VICTORIA.

immediate vicinity of the port, and the openness of the bay, which rendered it unsafe for shipping during the prevalence of certain winds, caused it to be thought an unsuitable site for the chief town. This was eventually founded at the northern end of Port Phillip Bay, by two parties—one led by John Batman, who landed on May 29, 1835, and the other by John Pascoe Fawkner, whose party arrived at the site of Melbourne on Aug. 28 of the same year. Both these parties were from Van Diemen's Land; and they were soon followed by others from the same island and from Sydney, who brought stock with them, and began to push their way into the interior. These were met by Major (afterward Lieutenant-Colonel Sir) Thomas Mitchell, who, entering from New South Wales on the north side, and traversing a considerable portion of the as yet unknown territory, was so struck with its wondrous capabilities that he named it "Australia Felix"—the aptness of which name a subsequent knowledge of the geniality of its climate, the excellence of its soil, and the then unexpected richness of its mineral treasures has fully justified.

The reports of Sir Thomas Mitchell and the success of the first settlers caused great excitement, not only in the Australian settlements, but in the mother country. Herds of sheep and cattle, driven overland from New South Wales, speedily occupied the best parts of the new territory.

Every available vessel capable of floating was put into requisition to bring passengers and stock from Van Diemen's Land; and after a time, ship loads of emigrants began to arrive from the United Kingdom. Regular government was first established under Captain William Lonsdale, who, having been sent from Sydney to take charge of the district, landed on Sept. 29, 1836; and on March 2 of the following year Sir Richard Bourke, the Governor of New South Wales, visited it, and named the metropolis Melbourne. Mr. Charles Joseph La Trobe arrived on Sept. 30, 1839, having been appointed to the principal official position in the settlement, with the title of superintendent, which was changed to that of lieutenant-governor when, on July 1, 1851, it was separated from New South Wales and erected into a separate colony, under the name of Victoria.

The separation of Victoria from New South Wales was the result of strong and persistent agitation by Victoria. But it must be remembered that at that time communication between Sydney, the capital of the parent colony, and Melbourne, by a coasting voyage, took at least three weeks, whereas now an express railway train runs each way daily, occupying a little more than one night. The next few years were remarkable in the history of Victoria. Gold was discovered by a shepherd toward the end of 1848, but he kept his discovery secret for some time, and only revealed it two years later to a friend who nursed him through an illness. It was in 1851 that the existence of gold became an established fact, and it was soon discovered in such quantities as to spread the fame of the Victorian gold fields throughout the civilized world, and a great and sudden influx of population was the immediate result. The largest nugget ever found was discovered by a party of diggers at Dunotly, and named by them "The Welcome Stranger." It weighed 2,280 oz., and represented a value of nearly £10,000. During the height of the gold fever large fortunes were made, and in many instances recklessly squandered, and men who flocked to Victoria from all parts of the world underwent strange vicissitudes of riches and poverty, and all more or less hardship, at the "gold diggings." After a time, some discontent arose among the diggers, in consequence of the oppressive character of the mining regulations, which culminated in riots, which occurred on the Ballarat gold fields toward the end of 1854. The disturbance was soon quelled, with some bloodshed on both sides, and the grievances complained of were afterward redressed.

A new constitution, giving responsible government to the colony, was proclaimed, on Nov. 23, 1855, and since then, though political struggles have been frequent and party feeling has at times run high, these circumstances have had no permanent effect in setting class against class, or in any way lessening the good feeling which exists between all sections of the community. At times commerce has been depressed, but this has soon revived; and the material prosperity that the colony has enjoyed, upon the whole, is perhaps without a parallel in the history of any country.

A few facts, taken principally from the Victorian Handbook, which has been specially prepared for the Victoria Commission of the Paris Exhibition now in progress, may be of interest to our readers.

Climate.—"It is the finest climate in the world." Such is the verdict of all colonists who have resided in Victoria. The season termed winter is simply the period in which there is more rain and less warmth than in summer. Few residents of the low-lying portions of Victoria have seen snow fall; but in the higher altitudes it is plentiful in the winter. On the mountain ranges there is occasionally a thin covering of snow, which may whiten the ground for a few hours. The native trees are always green, and do not shed their foliage during the winter. On the other hand, the European trees planted in the colony undergo the usual transformation.

Cattle and sheep remain in the open air the whole winter through, and fatten on the winter pasture without extra fodder. Farmers in Europe and America, who know what the expense and trouble is of organizing winter quarters for their stock, can understand the advantages Victoria possesses in this respect. The mean temperature of Melbourne is 57·3 deg., and is about equal to that of Washington or Marseilles; while the average rainfall is 25·75 in., approximating with that of the Isle of Wight.

Soil and Agriculture.—The soil of Victoria is of volcanic origin, very friable, and of a brownish color verging into chocolate. It is so rich as to be adapted to all kinds of vegetation without requiring fertilizing accessories for periods of many years. The average yield per acre, extending over a period of seventeen years, for the principal crops is—for wheat, 12 bushels; oats, 16 bushels; barley, 20 bushels; potatoes, 3¼ tons; hay, 1¼ tons. In the last twelvemonth, the extent of land returned as under cultivation amounted to 2,576,405 acres, as against 2,417,582 acres in 1886-87: the increase shown by the figures was, therefore, 158,823 acres. The average area in cultivation to each person in the colony was about 2½ acres in the year under review, as against 2¼ acres five years previously, and 1¾ acres ten years previously. The colonial laws afford great facilities of taking up land for cultivation; any person can take up 320 acres for agricultural purposes, payment being arranged at the rate of 1s. per acre per year until 20s. per acre are paid, with the option of either paying the balance of 20s. after the seventh year, or allowing payments to extend over the entire twenty years, the former meanwhile enjoying possession. An agricultural college has also been established in which pupils may train for agricultural pursuits. Fruits grow in abundance, and experience has proved that all the different kinds grown in England and Central Europe succeed equally well with those produced on their native soil. Already, Australian apples have found their way into the London market; and it is only a question of ascertaining an absolutely safe means of transport to assure a great future for this branch of industry, as the reversing of the seasons insures the arrival of the early kinds in London when the English market is practically bare.

The vine-growing industry claims separate mention. That a great future in this line is in store for Victoria has long been apparent to those who have watched the commercial progress of Australian wines in Europe; and, since the Colonial Exhibition in London, the imports into England have increased by leaps and bounds; while the Paris International Exhibition is destined to add to the reputation these wines have already attained. With a climate and soil admirably adapted to the vine in every respect, it is simply a matter of time and patience to bring the conditions of soil and the manufacture and treatment of the wines into touch with the requirements of the home markets. The art of wine making has not yet had the time to attain the same degree of perfection as in France. There exists in the colony no center of viticultural industry, as yet, even in miniature, resembling that of Bordeaux. But there is the certainty of a great fortune to be gained by establishing in Victoria large cellars to store wines purchased from the small growers, which would be stored until the proper degree of maturity has been reached for racking and bottling. There is also a want of French experts to instruct the Australians in the art of manufacturing champagne, as well as the ordinary white and red wines.

As is well known, wool and gold are the two staple products in which this colony holds the highest position. The value of wool exported in 1887 was over five millions sterling, and the quality is indisputably the finest in the world. The production of gold, which had steadily fallen off since 1858, is now about stationary, but the opinion still holds that there are large quantities of gold yet undiscovered in the colony. In manufactured goods great progress has been made in the last few years, and, in spite of the large importations from Europe, there are few objects either for necessity or luxury that the colony is not in a position to supply locally.

With regard to work and wages, Victoria, like the rest of Australia, is the "workingman's paradise." Domestic servants' wages are especially high. Laborers, mechanics, and artisans all enjoy a far higher rate of wages than in Europe, while the necessities of life, meat, vegetables, bread, etc., are less dear than in Europe. But the workman and his family eat meat three times a day, and buy new clothes at least once in six months. The labor organization represented by trade unions is in a more advanced condition than perhaps in any European country. Every year, in the month of April, there is held a workmen's fete, called "Eight Hours Day"—*i. e.*, the anniversary of the custom, now almost universal, of the eight hours system—this being now the settled period of a day's labor; and it has been permanently established without any law other than that of custom. There is a grand procession through the city and suburbs, headed by banners and music; it is looked upon as a more important demonstration than the lord mayor's show in London, being frequently viewed by the governor and his ministers.

The railway lines and telegraph system in Victoria are the property of the government, and have been constructed with capital partly borrowed in the London market for the purpose. The public debt of the colony has been contracted principally for railways. A large number of new lines have been recently constructed, and the total amount now open is considerably over 2,000 miles, while lines are being made at the rate of 300 miles per annum. The loans contracted by Victoria can scarcely be looked upon as an ordinary debt, inasmuch as it is well known that the railways could at once be sold for more than the amount of the total debt of the colony. The revenue from the railway is more than sufficient to pay the interest on the national debt of the colony.

The metropolis, the city of Melbourne, is one of the most beautiful capitals of the world; it is also the most important and populous city of the southern hemisphere. Including the suburbs lying within a ten mile radius of the town hall, it contains 450,000 inhabitants. It is laid out in the American fashion, with streets at right angles, very wide and well paved and lighted. A large number of trees are planted in the principal thoroughfares, adding greatly to the appearance of the city. The buildings are not only fine, but many of them possess great merit from an architectural point of view. The cathedrals (each religion with its own), the houses of parliament, treasury, town hall, post office, law courts, custom house, university, public library, clubs, theaters, and many other buildings vie with similar public edifices in the Old World. The various banking institutions are in buildings which would adorn a European capital. The river Yarra, originally little better than a large ditch, has been widened and deepened so that even now large ships drawing 20 feet of water are brought up to the shallow shores. This process is still going on, and the depth is to be 26 feet. The shops and warehouses would compare favorably with those of the great cities of Europe. The city is furnished with a cable tramway system, which is recognized as the best existing. The tramways run through the principal streets to all the suburbs, and have a total length of about fifty miles.

Everything which renders life easy and agreeable may be found in Melbourne. The prosperity of the city is shown not only by the surburban mansions of the rich, but also by the thousands of charming villas and cottages spreading many miles out from the town, and giving an air of well-being and contentment it would be difficult to find elsewhere. The humblest cottage has its water supply, including a bath. The large reservoir known as the Yan Yean, situated about twenty miles from Melbourne, furnishes the total supply for the city and suburbs, reaching during the summer months a daily consumption of 29,000,000 gallons.

There are many fine public parks and inclosures in and around Melbourne. In no town in the world has the workingman more enjoyments and privileges. There is no state religion, all creeds being equal in the eyes of the law. Churches are sustained entirely by voluntary contributions. The state provides education, which is free of cost, secular and compulsory. The parents of those children who do not attend the state schools are obliged to furnish a proof that their education is carried on privately. For the higher grades of education, there is the Melbourne University, to which many persons who set foot on Victorian soil without a penny are now in a condition to send their children. There is also a Workingmen's College, founded by the late Hon. Francis Ormond, a commissioner for the Paris Exhibition, which has already 2,000 pupils. Women are admitted, on equal terms with men, to an institution which, if not to be compared with the great conservatories of the Continent, proves at least that the value of technical instruction is recognized in Victoria. The public library, picture gallery, museum, botanical and zoological gardens offer combined recreation and instruction to the mechanic as to the clerk and shopman. A large number of scientific and literary societies exist in the city, besides mutual aid societies, musical societies, orphanages, benevolent institutions, mostly on the scale of those in great European centers. In the matter of amusements, Melbourne possesses fine theaters—of which the Princess Theater would be worthy of London or of Paris—and numerous concert halls. But it is principally in the open air that the Victorian takes his enjoyment. Australian cricketers are too well known to require any comment, but football matches are next in favor, sometimes attracting 20,000 spectators. Horse racing is very popular, and the gathering on the cup day at Flemington may be compared to the Derby or Longchamp as a brilliant assemblage, without that roughness which, to the sensitive mind, is often a drawback to the enjoyment of the course at Epsom.

But Melbourne is not the only large town in Victoria, although by far the most important. Ballarat, the City of Gold, is situated about eighty miles in the interior, and is in many respects a fine city, the streets being modeled to some extent on those of Continental towns. Sandhurst ranks next to Ballarat in importance. There is also Geelong, on Port Phillip Bay, once the rival of Melbourne. At both Sandhurst and Ballarat are schools of mines, to which are attached museums containing technical and geological specimens, models of mining machinery, and geological plans. Geelong is in the center of a pastoral district, and is also noted for its manufacture of tweeds.

Progress of the Colony.—It is hardly fifty-three years since the first European settled in Victoria. Now it contains over 1,100,000 inhabitants. The colony has a network of railways in every direction, and is dotted over with prosperous towns. The imports are valued at over £20,000,000, the exports at £14,000,000. Last year the gold production was 625,000 oz., value £1,270,000; the value of sheep and cattle raised was £9,000,000; and the agricultural produce, £7,500,000. The revenue of the colony for the present year is estimated at about £9,000,000.

There are in every direction state schools, churches, newspapers—of the latter, five appear daily in Melbourne. There is an observatory, of which Victoria is justly proud, and the naval and military forces are large in proportion to the population. Volunteering is popular throughout the colony, and the number of men between the ages of twenty and forty is over 100,000. Victorians are proud of their colony, but they are also proud to have British blood in their veins. More than 95 per cent. of the population is British or of British origin, and England is always spoken of as "home," even by the youth of the colony, who learn the expression from their parents.

There is a fine field in this colony for men of energy and enterprise, for an immense part of the country still remains to be opened. The tendency in Victoria, as elsewhere, is to centralize in the towns, and the urban population represents a proportion of more than one-half the entire colony. Probably too many give their attention to the manufacturing industry, and young women prefer the shop and factory to domestic service, although the latter is more lucrative and less laborious. The most desirable immigrants are, on the one hand, domestic servants, on the other hand, farmers, vignerons, and, in fact, all those who turn their attention to the cultivation of the soil.

In reviewing the colonial advance made by the colony in its short existence of fifty years, one is inclined to ponder on the possible future to so brilliant a beginning. To show the advantage that such a colony is to the mother country, the 1,000,000 population resident there made purchases during 1888 from outside sources to the extent of £24 per head of the entire population, probably the largest purchasing power of any community of the known world.

Victoria has often raised her voice in favor of the federation of Australia. It is a pity that a more representative show of the united colonies was not made at the present World Show in Paris. It has fallen principally, almost entirely, to Victoria to represent the Australasian group, when it should have been a matter of federal action. But time slipped by, and it was too late to take concerted action. The government of Victoria appointed a royal commission, with the Hon. W. F. Walker, the then commissioner of trade and customs, as president, and Mr. E. A. Huybers as secretary, in Paris, together with a representative body of commissioners. Exhibits were confined principally to the natural products of the colony, such as wine, wool, gold, specimens, etc., and though the show can hardly be said to fairly represent what the colony is capable of producing, the representation has been a great success, and the nature of the awards has proved that in the staple products of wine and wool the colony can hold her own against the world.

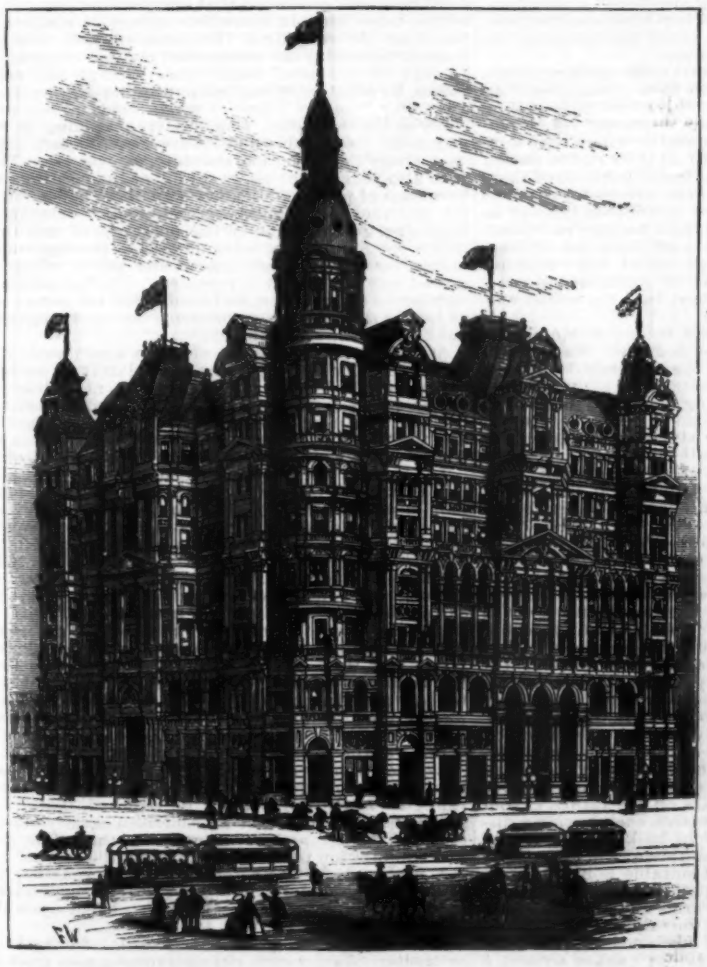
There are three separate courts. One is situated in the main building, close to the British commission; a second is on the Quai d'Orsay, while a separate wine chalet is built in the Trocadero Gardens, close to the

western wing of the palace. On the Quai d'Orsay, the representation of Victorian natural scenery has proved a great attraction, and the Australian ferns have flourished splendidly. A special feature is the native encampment showing the *mia-mia*, or native hut, as constructed by the natives.

Although the official list of awards has not yet been published, it is understood that the Victorian wines have won a grand prize (the highest honor obtainable), also nine gold and twenty-eight silver medals—an average which places Victoria in a first position as a wine-producing country. The wool, leather, and timber exhibits have secured high honors, and a grand prize has also been awarded to the commission for the

THE EXHIBITION BUILDING, MELBOURNE.

COLLINS STREET, MELBOURNE.



THE FEDERAL COFFEE PALACE, COLLINS ST. WEST, MELBOURNE.

THE GENERAL POST OFFICE, MELBOURNE.

beautiful collection of ferns.—*Illustrated London News.*

THE ARMY OF KUKUANALAND.*

By OTHO ERNEST MICHAELIS, Ph.D., United States Army.

I HAVE had many misgivings whether or not the subject of to-night would yield material worth your hearing. That it will not prove unmitigatedly stupid, I hope—relying upon the apparently uniform interest that all good citizens take in military matters, either in vivid narrations of actual experience or in open discussions of present or future policy. I suppose the majority of my hearers have read Rider Haggard's "King Solomon's Mines," and will recall Allen Quatermain's clear and simple story of the journey to Kukuanaland. You may recollect that in the introduction, Quatermain, recounting the many things upon which he might have dilated, mentions the "most interesting subject of the magnificent system of military organization in force in that country." Ignosi was, you remember, placed, by the aid of Quatermain and his friends, upon the throne, which his bloodthirsty Uncle Twala had usurped. After his thirty years' wanderings among civilized nations, with his quickness of perception, his retentive memory, and his facile adaptability, you may be sure he did nothing to lessen the military ardor and prestige of his people; on the contrary, he taught them all that he believed admirable, the matured results of long experience, observation, and reflection. Upon these results, relating both to technical military details and to the broad questions of the relations between the people and the army, I propose to dwell this evening. Kukuanaland has no seaboard, and, consequently, Ignosi's genius avails us little in assisting to a solution of what is to us the question of the hour—but it had neighbors to be feared.

You remember that Infadoos told Quatermain, soon after his entrance into the land, "When Twala, the king, calls up his regiments, their plumes cover the plains as far as the eye of man can reach." "And if the land is walled in with mountains, who is there for the regiments to fight with?" "Nay, my lord, the country is open there," and again he pointed toward the north; "and now and again warriors sweep down upon us in clouds from a land we know not, and we slay them."

At the battle of Loo, Quatermain had a good opportunity of observing the conduct of the soldiers, of whom he says, and this will give you some idea of the character of the material upon which Ignosi worked, "Never before had I seen such an absolute devotion to the idea of duty, and such a complete indifference to its bitter fruits." In this instance they were "foredoomed to die."

Indeed, in that day, before Ignosi reigned, Quatermain tells us that, "In Kukuanaland, as among the Germans, every able-bodied man is a soldier, so that the whole force of the nation is available for its wars, offensive and defensive."

It is not necessary to give in detail the conversations carried on with the Kukuanian officials. It will suffice to report the conclusions in our own language, and I propose to present to this evening's audience only the more salient features of their military system, such as strike me as possessing general interest.

Considering its extent and population, the standing army of Kukuanaland is very small; but as its

* A lecture delivered before the Franklin Institute, March 11, 1887.—*From the Journal.*

strength was fixed by the experienced Ignosi, we must assume that it was large enough for the needs of the country.

Kukuanaland is a land of workers—one person in every three of the whole population has a special trade or occupation; one in every seven is a farmer or stock raiser; one in every 800 a lawyer; one in every 770, a clergyman; one in every 600, a doctor; one in about every 200 is a teacher; and one in every 2,000, a soldier.

"Soldiering" is, consequently, in Kukuanaland, a select profession. The term of enlistment is short, three years, the pay is excellent, increasing with length of service; the chances of promotion fair. In case of death in service, a liberal pension is provided for dependent survivors. After eighteen years the soldier may retire on half pay; after twenty-four years, on three-quarter pay; and after thirty years, or in case of disability, on full pay.

After one enlistment, honorably terminated, the soldier has the first right to present himself for examination as a candidate for any vacancy occurring in the civil service of the government, for which he has presumable qualification. Soldiers are prohibited from marrying, a wise provision, as will be seen, consistent with Ignosi's prominent motive, the maintenance of a natural military spirit among the people; an economical one, as it tends to keep the retired list small; for the natural desire of man for family relations induces many young soldiers to decline re-enlisting after having served one or more terms. One hundred officers are appointed every year, who must all be taken from the army, in compliance with rules and regulations which will presently be mentioned. The age of original enlistment is between seventeen and twenty-two years, excepting for graduates of special schools, who may be twenty-five; all soldiers between these ages are eligible for detail as cadets at the government military college, and the selection is entirely dependent upon their own aptitude and application, as determined by annual examination.

As a result, every vacancy in the army is eagerly sought for; the candidates for enlistment being so numerous that the government has been compelled to establish the most rigorous limiting rules.

The privilege of filling a certain number of annual vacancies has been granted to the advanced schools and colleges in the various provinces of the country, whence candidates are accepted on competitive examination. Many bright, ambitious young men enlist, not only to gratify inborn military instincts, not only with the hope of promotion, but also to qualify themselves as candidates for civil positions. Ignosi's wise policy has already borne fruit, for experience has shown that the young man who has the ability, both mental and physical, to serve with credit at least three years in the army, as a rule is a successful aspirant for the civil appointment.

As about one man in every hundred in Kukuanaland is a government employe, it is readily seen that gradually a large, available, well trained military reserve is forming without the slightest additional expense, for all officials must serve in the local reserve, of the formation of which I will say a word in passing.

The country is divided into departments, whose extent is mainly determined by geographical considerations. Each of these departments has its own organized reserve, in which service for three years is compulsory upon all men over twenty-one years of age, not otherwise exempted, and with which, as already stated, all government civil officials must, in time of peace, serve. The reserve is armed, equipped, clothed, and, while in practice encampment, fed and paid by the state. Army officers, line and staff, are detailed, in the various departments, to higher reserve positions, to insure uniformity of drill and methods.

The army is apparently numerously officered, about one officer for every ten men, but when the nature and scope of their duties are considered, the number is not too large.

There is only one way in Kukuanaland to a commission—by enlistment. As a rule, the line appointments are made from those soldiers who have successfully passed through the course at the government military college, but not unfrequently some bright non-commissioned officer will compete successfully for an appointment with the graduates of the school.

The general staff of his army has been a subject of much thought and study with Ignosi. It appears rather large for the mere wants of the standing army, but the king constituted it to meet the requirements of the nation even in case of a great war. Having made wise provision for the constant existence of a strong and available military element among his people, he yet felt that the special and technical duties so vitally important for the successful prosecution of war could satisfactorily be performed only by men professionally competent. Hence the *personnel* of his grand staff was large enough to furnish representatives, in case of war, to all the principal subdivisions of the army, and for the charge of all its main supply and manufacturing depots. While thus able to deal with the affairs of an active army of one million of men, its functions, in time of peace, were so directly connected with their welfare that the people were well content both with the number and rank of the general staff officers.

As with all other branches of the service, these officers are appointed from the ranks after competitive examinations.

To obtain officers for the scientific and technical staff corps, Ignosi has availed himself of the studious and industrial characteristics of his people. Scientific and technological schools are found everywhere in his dominions, and their graduates or advanced students, after enlistment and special *military* training at the government military college, are examined competitively for positions in the branches of the staff. When vacancies occur, examining boards are appointed in every military department of the country, and those who pass these boards are ordered to Loo, the capital, where a final examination determines the successful candidate.

The *elite* corps in the Kukuanian army is the inspector-general's. An assistant inspector is appointed yearly from the captains of the army. The candidates, selected by the primary boards, are finally examined at Loo by a board consisting of the commanding general of the army and the chiefs of the grand staff. As a result, all the captains are ever studying to reach this goal, and the inspectors are consequently the brightest men in the army.

A peculiarity that characterizes the administration of military justice in Kukuanaland is worthy of mention.

There are no courts-martial, such as are familiar to us, except for cowardice, desertion, and other capital offenses committed in the presence of the enemy, and for spies caught red-handed. Judges properly assigned preside at all military trials, and officers constitute the jury, which renders a verdict, following the civil law, by a majority vote. The statutes fix the punishment.

Officers may retire after twenty years' total service, on half pay; after thirty years, on three quarter pay; after forty years, they may, and after forty-five years or in case of disability they must, retire on full pay. As in the case of enlisted men, liberal pensions are given to dependent survivors. Officers are not permitted to marry before they have been ten years in the service. Here again Ignosi has shown his far-reaching wisdom. For most active, exposed service, he has always at command a large body of eager, enthusiastic young men, untrammeled by immediate family ties. The retired list is kept within limits by the numerous resignations of those desiring "to take unto themselves wives," and who, as a rule, at once become applicants for civil appointments, and thus, in most instances, become important factors in the potential government reserve.

Of course my limits this evening are too narrow to permit my entering into a full and detailed account of the manner in which the Kukuanian army is armed, equipped, clothed, and fed. This must be reserved for some future occasion. Still, I believe that a recital of some of the deviations from accustomed ways, well known to you all, together with a brief *resume* of Ignosi's reasons, be they good or bad, for such deviations, may not prove too great a strain upon your patience and good nature. In his wanderings Ignosi had become fully convinced of the truth of the nineteenth century canon of taste, that the useful must be the beautiful, that the fit, in its simplest form, is most pleasing, and he felt that the sooner the military taste of his countrymen was educated to appreciate the justice of this standard, the sooner they would become imbued with a more exact military spirit, reflexively producing an abler military service. He had seen in older countries famous horse guard sentinels and their congeners still entrancing the eyes of servant maids and footmen, he had seen the bright colors and glittering trappings of holiday soldiers evoke the plaudits, yet want the respect, of crowded streets, and he had seen thousands of earnest men fighting for a principle, as freemen should, without crimson and gold. It was his ambition then to make the Kukuanian soldier a respected working member of a busy community, a man who need not blush because his tools, his clothes, his life, were the useful concomitants, the proper exponent, of his profession.

As Ignosi had no desire to make the military a class apart, but, on the contrary, to have it considered an essential and appreciated portion of the body politic, he has been more impressed with the self-voiced personal wants of soldiers, in countries where they were patriotic citizens, endowed with all their rights, duties, and feelings, than with the enforced methods of those other countries who maintain great armies for dynastic reasons, where soldiers were considered merely as "food for powder." Ignosi had become convinced that the ideal soldier would work hard, march long, fight well, starve, thirst, and go naked, but would not embarrass himself with what he considers unnecessary burdens. He acknowledged that the soldier citizen would not be a pack mule.

In this respect the soldier's feeling is simply an unconscious evolution of the *Zeitgeist*. Steam, electricity, air, the locomotive, the telegraph and telephone, and the balloon are mighty activities, not changing, but widely extending the underlying principle of all warfare. A battle is an amplified prize fight. When our modern gladiator stands in the arena, his antagonist establishes himself just beyond arm's length. This idea determines battle formations. The opponents array themselves just beyond the natural range of their weapons. Hence, since the first battle between Hercules and Antæus, the formation distance between combatants has increased directly with the reach of their arms. A line of battle may be likened to a Briareus. His many arms cover all the ground in front, and to the right and left of him, and hence follows not only space between, but also extension of the lines. So to-day, electricity and aeronautics afford the master mind, the commander-in-chief, a practical *coup d'œil* almost illimitable in extent as compared with the *terrain* of former days. Steam gives him the ability to place men and material rapidly where they are most needed. Ignosi recognized this modern condition of warfare, instinctively felt and acted upon by patriotic soldiers, and arrived at the inevitable conclusion that, all else being granted, *mobility*, power to accomplish long, arduous, *rapid* marching, was the great *desideratum* in the wars of the future. Campaigns would be short and decisive, each having a distinct objective, and supplies in bulk for repair and recuperation, for renewal or continuance of operations, would have to be massed at suitable points, near in time, independently of the operating column. Hence his soldiers carried only their arms and ammunition, a haversack with a capacity of four days' rations, a tin cup able to stand the fire, a combined tin plate and frying pan, forming a meat can (a Yankee notion), a fork, knife and spoon, a canteen for water, and a hunting knife.

A soldier thus "outfitted" is before you on the screen. The hunting knife, of a special design, originating with Lieutenant Rodman of the United States army, is worth dwelling upon for a moment. The shaft is built up of leather washers on the tang, and the blade has the cross section shown, heavier toward the back, so that it may be handily used for hacking. In combination with the blade it can be utilized in emergency in throwing up effective temporary intrenchments. Carrying burdens is always a disagreeable necessity, and hence everything should be done to make it least irksome. You see here that the chest is left almost unrestricted, and a zinc shoulder pad has been attached to the haversack and canteen straps to overcome any possible discomfort resulting from their stringing. Ignosi deemed the fairly accurate judgment of distances as the most important element in military firing. It is a quality that few men can acquire intuitively. He accordingly supplied every individual in his army, officers and soldiers, with telemeters, instruments for determining the distance of an enemy. No complicated mathematical apparatus is practicable; the instrument must be simple in manipulation, and give instantaneous correct results. He has adopted this simple little device, the invention of Colonel P. Le Boulenge, a distinguished Belgian officer, which gives the distance by noting the time elapsing between the flash and the report of the enemy's fire, and automatically translates this time into yards, as the air velocity of sound is known. It makes allowance for changes in this velocity with varying temperature, and includes a correction for an average personal equation. The officers carry this little instrument in their pockets, and the men in the butts of their guns. It is here on the screen, where you can also see depicted the method of using the musket telemeter. One additional important use is worth mentioning. By observing the explosion of a shell, its range is determined. The error of the instrument is within the dangerous space of modern weapons. Ignosi has abandoned the bayonet in his army. Still, as a ramrod is a necessity with an arm using metallic ammunition, on account of an occasional failure to extract, he has availed himself of this necessary appendage, and has made it available as a pike. I take pleasure in stating that this ingenious device is due to an American officer, Colonel Buffington. Its method of operation is shown on the screen.

For carrying small-arm ammunition for single loaders, Ignosi has adopted the Mills cartridge belt, before you. The cartridges are easily taken out of the loops, as you see. The greater portion of the Kukuanian army is supplied with a rapid-firing single loader, a most excellent weapon, but for two reasons Ignosi has determined gradually to adopt a repeating gun, one that shall be as good as the best single loader, and yet when occasion demands be an efficient magazine arm. These reasons are, first, in an engagement, a crisis may come when it is of vital importance to deliver a rapid continuous fire, a veritable *feu d'enfer*, without taking the piece from the shoulder, and, secondly, because in winter campaigns the cold may so benumb the fingers that the handling of single cartridges becomes awkward. When a man pummels you, you must choose one of two possible alternatives, pummel back or run away. So in battle, and I shall have to revert to this idea in speaking of the Kukuanian target practice, men *will fire* at each other, and with modern breech loaders, even a few minutes' firing entails enormous expenditure of ammunition. The combatant first out of ammunition is apt to reserve further fighting for another day. Ignosi, influenced by these considerations, concluded that every soldier going into action must carry in immediate accessible shape not less than 150 cartridges. He accomplished this by radically changing the accustomed method of packing. Instead of the usual small boxes holding the cartridges, he substituted endless muslin bands, furnished with fifty "casings," each of which holds a shell, precisely as the belt does. Immediately preceding an engagement, two of these bands are given to each man, who slings them over his shoulder, as you see. This plan also permits the ready supply of the fighting line by means of pack mules laden with these bands ready for distribution. Ignosi has adopted a detachable magazine gun, apparently the only form of arm that fulfills the condition of being as good as the best single loader, for it is a single loader, and yet is, when required, one of the best of repeaters. For the personal carriage of ammunition, he has adopted the same plan as for the single loader, a magazine belt and magazine bands, as is shown on the screen.

As regards cavalry, Ignosi acted in accordance with conclusions founded upon the general drift of modern experience, and upon the inevitable necessities of future battle formations. The results of experience induced him to consider cavalry as mounted infantry, and the "trooper's" special equipment differed in no respect when mounted from what it was when afoot.

The horse is furnished as a means of rapid transportation, and everything additional carried was intended for *his* comfort, and not for the rider's. Ignosi recalled the telling effect of even small weights upon the animal's endurance, as shown especially in handicap races, and he insisted that the living vehicle should be laden as lightly as possible, hence the horse carried nothing but what was needed for his health, his sustenance, his security, his management, with a single exception to be presently noted. The necessities of future battle formation, by which Ignosi meant, in a word, greatly extended lines, require that the commanding general should have it in his power to hurl a sufficient force rapidly, unexpectedly, upon some exposed point, and therefore Ignosi provided for heavy *mounted* reserves, that could be promptly entered at the weak spot.

As the ordinary carriage of the rifle and reserve ammunition would prove impracticable in such fierce riding as might on occasion be required, Ignosi has adopted the invention of an American cavalry officer, Captain Hunter, and has attached to the saddle, gun and ammunition pockets, as shown on the screen.

A few words on the Kukuanian target practice are in place here. Ignosi had observed that a mark which fired back had a decidedly quickening effect upon the marksman.

As remarked already, fired at necessitates firing back or shelter. Under such circumstances a man must be kept busy; the immediate work at hand is firing his piece, and he will peg away as long as his ammunition lasts, and as rapidly as his arm permits. Under such exciting strain, the average soldier will not tarry to assume correct school positions for aiming and firing, he will "blaze away."

Ignosi had seen men, tolerably taught soldiers, firing under excitement, and he had noticed that as far as aiming was concerned, they had apparently recalled the axiom that two points determine a straight line, had drawn a "bead" from the rear sight to the object, and had contentedly fired. The result is shown on the screen. To make certain that at least the muzzle of the gun is presented at the object, Ignosi attached to his arms a small tube as rear sight. You see that if the piece is at all aimed, it must be pointed correctly.

To simulate the excitement, shifting distances, noise and smoke of actual battle, Ignosi provided for prac-

tice movable skeleton targets representing advancing lines, which were pushed by small steel-clad traction engines, whose shrieking and puffing gave life to the movement. In addition, each was furnished with a small Gatling, firing blank cartridges, whose sharp reports, by their aggressive suggestiveness, enhanced the value of the practice. Of course he had exact sharpshooting competitions at long ranges, one feature of which is worth mentioning. No marker was ever exposed during practice. A bullet-proof shelter was placed in front and to the side of the target. In this the observer recorded the hits by means of a lens and reflecting prism upon a miniature target, which formed part of a *fac-simile* telegraph circuit. The marksman thus saw at once at his side the exact position of his hit.

Ignosi has made artillery a special subject of study; he recognized its predominant importance, for he had seen one of the greatest wars of modern times decided by a superior artillery opposed to a better armed infantry.

In his study of this branch of military science, he had been struck by the fact that, with the exception of the recent general introduction of rifled guns, whose superiority had been foretold a century and a half ago, there had been no radical change since the original introduction of cannon as an offensive arm. There had been many changes of detail, necessitated principally by modern improvement in manufacturing processes, but aside from these, in its general aspect, he found the artillery of to-day what it had been in the wars of Frederick and Napoleon.

In the equipment of infantry, the great underlying principle of modern warfare had been relentlessly applied, everything that was not absolutely essential had been lopped off, everything had been surrendered for the attainment of the cardinal requisite, mobility.

Artillery carriages have been strengthened, guns have been strengthened and are now loaded at the breech, powder has been strengthened, but no emphatic departure from the old system has been obtained.

The complete carriage, the *fourgon*, the wagon that carries the pieces, is to-day in principle what it was when Gustavus Adolphus adopted it.

The battery wagon and forge, one-third of the battery effective, are apparently deemed as necessary to-day, when every campaign condition has changed, as they were during the march to Moscow.

He found that the projectiles of to-day, all metal, weather-proof, the powder of to-day so dense as to be almost moisture repellent, guarded as jealously as when soft wood sabots had to be kept from swelling, as when the loose, absorbent, explosive mixture of the days of yore was cherished as a precious, mysterious, sensitive chemical.

Ignosi had studied the cause of this universal adhesion to traditional requirement. He had endeavored to discover the reason why this most important arm of the service did not progress in sympathy with the *Zeitgeist*, the remorseless pruning spirit of the age. He attributed it to the influence of heredity; he considered it a most remarkable instance of the persistence of ancestral traits.

When guns were set up for battle use they were rare and complicated constructions, replacing, not because more simple, but because of greater power, cumbersome mechanical devices, like catapults, whose services required artificers, skilled for the time, and not combatant soldiers.

These first cannon occupied fixed positions, as did their prototypes, required equally complicated service, and their attendants were out of the hand-to-hand din of the fight.

Ignosi noted that although cannon and arquebuse were almost contemporaneous in development, yet, curiously, their use blindly followed the rule of the bow and the trebuchet. A feudal serf could bend the bow, therefore *he* could use the missile weapon that replaced it.

It required science to operate the trebuchet, hence only peculiarly skilled men could be intrusted with its successor, the cannon. For centuries now, by a most marvelous exhibition of transmitted *esprit de corps*, this fictitious distinction has been cherished, and is evidenced to-day in the good-natured tolerance of the artilleryman for his brother soldier, the "mud crusher."

Of course, the complicated machinery of the middle ages has necessarily disappeared, but for every hampering element "downed," a new one, from Ignosi's point of view, has sprung into vigorous existence. To-day, the development of the capabilities of small arm fire requires as much science, personal skill, judgment, nerve for its useful application, as does the service of field guns.

A plucky fellow can go around the world on a bicycle, carrying his repair material in his pocket, but a four-gun battery, to the reproach of nineteenth century military progress, cannot apparently go through a short campaign, without trundling along a village smithy and a country store. Ignosi had looked aghast at the latest tools and stores to be carried in the forge and battery wagon, every item of which he had been assured was essential. You also have the opportunity —the lists and the note recalls the famous work, "*De omnibus rebus, et quibusdam aliis.*" Yet he had seen such a storehouse on wheels, which had gone through a four years' war, "turned in" with many of the original packages unbroken, explained by the captain's statement that he "had had something else to do than to paint and oil." The old glamor "doth hedge" everything connected with the artillery service, nowhere more pointedly shown than in the mediæval precautions still deemed necessary for the transportation of cartridges and projectiles for cannon, a far simpler problem to-day than the secure carriage of that equally essential element for the usefulness of the command, its supply of sugar. Ignosi was incontestably impressed with the existence of this inherited sentiment by the exhaustive discussions he had heard regarding the proper service of machine guns, the simplest of modern weapons.

An infantry officer is intrusted with fifty or a hundred men, he must teach them to aim, fire, and hit, he has numerous and variable personal equations to contend with, he must get his men habituated to the otherwise demoralizing effects of recoil, he must judge distances and correct errors, and his ability to do all this is not impugned. But mount a portion of these same barrels in a rigid frame on wheels, eliminate recoil and personalities, fire them by turning a crank, almost without the possibility of an accident, the successor of the archer must retire, and the descendant of the catapultist take his place. Ignosi determined to break through these trammels of tradition and to bring his artillery in sympathy with the military progress of the age, to make it as mobile as its twin sister, the infantry.

He took up the question in detail. 1. He considered the gun carriage and limber as a wagon; you see a fair exemplar of the usual vehicle on the screen. It is a wagon with a flexible reach and a rigid pole. Nowhere had he found such another construction. In all his wanderings he had never met a four-wheeler in which these conditions were not exactly reversed. Every wagon he had seen had a rigid reach and a hinged pole. As this was the universal method, Ignosi adopted it. He had heard artillery officers complain of the vertical "thrashing" of the pole as destructive to their horses. Many ingenious plans had been suggested for the amelioration of this evil, none of which, however, struck at its root.

Its cause is easily understood; the limber wheels meet an inequality and are checked; the rigid pole, owing to the pressure of the trail, goes up, the carriage wheels next strike, the trail goes up and the pole down, to the great discomfort of the horse. Hence, in traveling over rough ground, there is a constant scissors-like opening and shutting between carriage and limber, transmitted, of course, in an increased ratio, to the end of the pole.

Yet, as artillery carriages cannot choose their roads, there must be *give* in the construction, customarily obtained in every-day practice by springs.

Furthermore, there must be a simple means of rapidly converting the gun wagon into a gun carriage, adequate to sustain the piece in firing. These two essential conditions have for centuries been well met by the established lunette and pintle connection, a strong junction, yet affording an easy, quick, and simple means of disjoining limber and carriage. Because it fulfilled these necessary requirements so satisfactorily, this joint has maintained itself to the present, notwithstanding that when it is considered a part of a gun wagon, it violates the elementary principle of teaming, a virtually stiff connection between front and hind wheels. A rigid pole is a logical sequence of a hinged reach, for in this case, as seen, there is no other provision for keeping the limber body horizontal, nothing else to prevent its continuous "wobbling" up and down. Ignosi formulated the essential qualities which his carriage must possess thus:

A rigid reach, a hinged pole, a universal joint arrangement, replacing the fifth wheel and springs of ordinary vehicles, a sure method for rapidly limbering and unlimbering.

It would consume too much time to describe in detail how he accomplished this—a model is before you, and the construction is shown on the screen. The reach is rigid vertically, movable horizontally, the limber "drawhead" can revolve, the pole is hinged vertically, the three together operate as a universal joint. The pintle is long enough to afford an instantaneous connection should circumstances demand it.

Mobility requires rapid maneuvering. The latest carriage has a turning angle of 55°—Ignosi's a normal turning angle of 90°, an emergency angle of over 100°. To attain this desirable end, Ignosi abolished the pintle hook and substituted a "drawhead," suggested by universal railroad practice. Usually this is checked by chains, yet allowing the spring to act slightly—thus saving many a shock to the horses. In actual combat the chains are unhooked, thereby giving the spring full play.

As the "drawhead" had to be long, it required support. Ignosi upheld it accordingly in the familiar manner, by a truss, as you see. But this interfered with the carriage of the time-honored ammunition chest, so Ignosi gave it up. He adopted an ammunition box, holding three rounds, weighing about fifty pounds, with cover cleverly fastened, as you can see, a device due to Colonel Williston, of the American artillery. Sixteen of these packing boxes, forty-eight rounds, a greater number than are generally carried, are placed on the limber, and are lashed, if necessary, just as any other load would be. The cartridges are packed in paper bags, perfectly water proof, hermetically sealed, and easily torn off in action. Ignosi designs that these boxes should replace the pouches used in carrying the ammunition to the gun.

When the limber becomes a two-wheeler, the simple device shown on the screen, a movable sleeve, locks the pole, and it may gallop off for further supplies, or be used as any cart might. A permanent seat is available for the cannoneers, and capacious receptacles are gained, in which everything necessary for casual repairs is carried, all without important change of dimensions, thus enabling him to dispense entirely with the ancient forge and battery wagon. For the rare cases in which a forge may be deemed desirable, Ignosi had adopted the miner's pattern, modified by Colonel Whittemore, and, as here shown, it is readily stowed in the limber boot. The occasions for its use in Kukuanian campaigns will be rare, for "cold shoeing" is an assured success, mild steel has replaced iron, and Ignosi has adopted the Clarke type of wheel, shown in model and on the screen, which can be "knocked down" and assembled without the aid of wheelwright or blacksmith, making the replacing of a broken felloe or spoke a very simple matter.

Ignosi had seen the destructive effects upon the carriage of the severe recoil strains due to modern light guns, long projectiles and heavy charges—this he endeavored to overcome by the device shown in model and projection, a recoil jacket, in which the gun moves very much as the piston rod does in the cylinder.

The spring "takes" the initial shock, and thus saves the carriage.

Ignosi placed the machine gun in the same category as the revolver: for offensive purposes he considered it the weapon of the instant. He adopted the latest Gatling with the Accles positive feed, rendering it available for fire at any angle.

As this gun can fire 1,200 rounds per minute, to make it an integral factor of an advancing line would require an amount of ammunition impracticable to carry with it. Hence Ignosi, while recognizing its great value for *defensive* purposes, each piece virtually representing under these circumstances a full company, did not deem it a feasible element in the engaged line of battle. His reserve, however, was plentifully supplied with Gatlings, each gun fully equipped with 3,600 rounds, *ready for use;* in other words, with thirty-six charged Accles drums, equivalent to three minutes' furious volley firing. He appreciated that in every great battle a moment might come in which a far-seeing commander, by a rapid concentration of aggressive force, without laying bare any portion of his main line, might, by the *coup de main*, overwhelm the enemy. And for this purpose he deemed the machine gun a valuable auxiliary *offensive* weapon.

The clock warns me that I must afford release to your compulsory attention, else I would dwell upon the many other changes made by Ignosi. I would like to describe, for instance, his artillery harness, planned upon that used with steam fire engines; to tell you how he got rid of the destructive punching and cutting of straps to make them fit; to dwell upon his barracks, his mess outfits, his simple methods of obtaining and accounting for repair material. I would like to go into details regarding the kind and quality of clothing used, to indicate the methods by which he secured unadulterated, unrobbed food for his men. But time forbids; I shall only add that he believed thoroughly that practical *ways* used and approved by the community at large must be good, and he therefore made it a fixed rule to apply them to the army *methods*.

The knowledge he had gained by his own experience, his method of gaining it, by friendly intercourse with keen thinkers, by constant, intelligent observation and examination of what the workers—they who strive hard for necessary profit—do, he grafted upon the military system of his country.

To us, Ignosi is an iconoclast. He has broken the idols of the fathers; he has dissipated the traditions of the ages; he has extirpated the last vestige of feudalism; and he has made the army of Kukuanaland of the people, for the people, loved, honored, *respected* by all.

PAVILION OF THE UNITED STATES OF VENEZUELA AT THE PARIS EXHIBITION.

BEFORE touching upon a description of the pavilion of the United States of Venezuela, and of the important collection that it contains, it will be well to recall, in a few words, the different phases of the country's history and to give a general idea of its geographical and political position, of its general statistics, and of the state of advancement and development of its chief industries.

Washed at the north by the Caribbean Sea and at the northeast by the Atlantic Ocean, bounded on the south by the Brazilian province of Alta Amazones and by the territories in dispute between Ecuador, Colombia, and Peru, on the east by British Guiana, and on the west by Colombia, Venezuela is situated entirely within the torrid zone, between south lat. 1° 40′ and north lat. 12° 16′.

The territory was discovered in 1490 by Alphonso Ojeda, a Spanish explorer, who sighted in the first place the lagoon of Maracaibo. The Spaniards, upon landing, seeing some huts that the Indians had established upon piles in order to raise them above the stagnant water that covered the plain, called the country Venezuela, that is to say, "Little Venice." They made a few attempts to establish themselves there, but without success. Later on, Charles V. definitely conquered the country, and in 1527 issued a decree that all the Indians who resisted should be enslaved. The conquest effected, Charles ceded Venezuela as a fief to the Velseres, rich bankers of Augsburg, with whom he had effected large loans. Under the administration of the delegates of the Velseres, who were solely occupied with the greed of gain, colonization made little progress, many Indians were reduced to slavery, and a large number were pitilessly massacred. In 1547, at the expiration of the lease granted the Velseres, Charles appointed a Spanish governor, Don Juan Perez de Tolosa, who founded Caracas in 1567.

Up to 1811, Venezuela remained under the dominion of the Spaniards. The war of independence lasted from 1811 to 1849, at which epoch the country was erected into a republic under the name of Colombia, and comprising three large departments, viz., Venezuela, Quito and Condinamaria.

It was not till 1830 that Venezuela took the initiative in the dissolution of Colombia, and formed itself into an independent state.

Since that epoch, Venezuela has passed through alternate vicissitudes of trouble and quiet. Peace was permanently established under the administration of President Guzman Blanco, now minister plenipotentiary to Paris. Finally, on the 5th of July, 1888, Dr. Juan Pablo Rojas Paul succeeded General Blanco.

As regards its productions, the country may now be divided into three well-defined topographical zones. The first is the agricultural zone, which occupies an area of about 185,000 square miles, and is comprised between the coasts and the plains or savannas. In this zone there still remains much unsettled land.

Scarcely 3,750 square miles have been cleared and partially cultivated since the conquest. There are included in this fifty bays and thirty-two ports, among which are those of Puerto Cabello, Maracaibo, Caracas, Cumana, and La Guayra. This portion of the country could easily feed seven million inhabitants. Caracas, which is situated in this zone, and which is the capital of the republic, is acquiring an ever-increasing importance. The city has more than 70,000 inhabitants, is lighted with gas by a company having a capital of $240,000, and is the terminus of four lines of railways running to La Guayra, El Valle, Petare, and Antimano.

The second zone is that of pasture lands or *llanos*. It is covered with gigantic grasses, and is the principal station for live stock. Nevertheless, some cultivated land is likewise to be found here. This zone embraces an area of nearly 155,000 square miles.

The third zone is that of forests, where we find woods, uncultivated mountains, and virgin forests. This zone, which is of incomparable richness, and in which abound rubber, vanilla, coquito nuts, tonka beans, and copaiba, and in which are found true natural plantations, would be capable of giving asylum to more than sixteen million inhabitants. The wealth of the soil is but very slightly exploited in the territories of Amazones, Caura, and Upper Orinoco. This latter territory is, so to speak, the retreat of the inde-

pendent Guarranos Indians, who, owing to their mild character and indolent habits, live on very good terms with the whites. The forest zone covers an area of nearly 305,000 square miles.

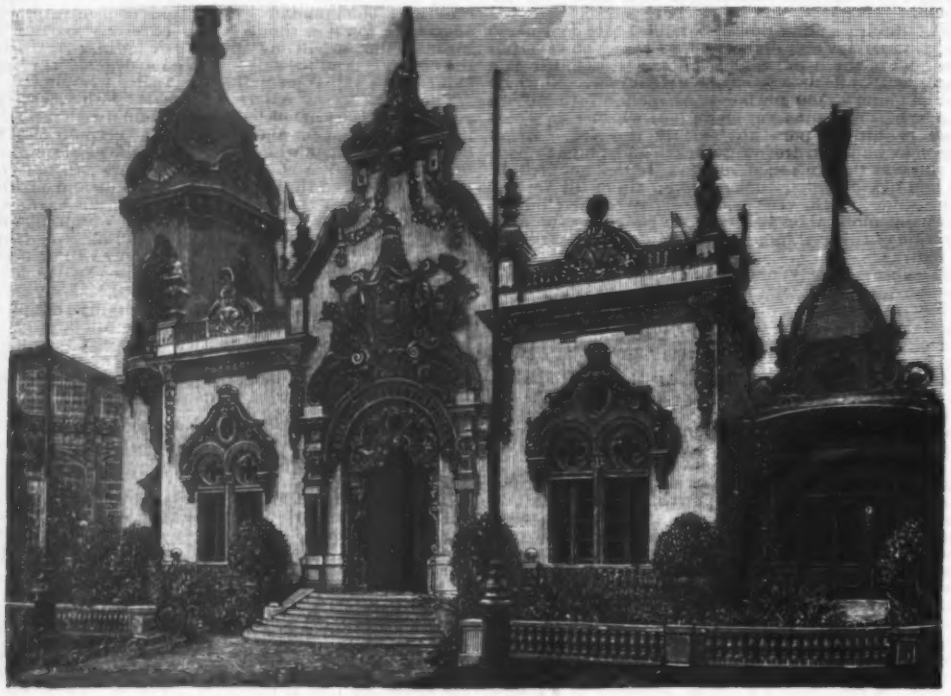
The exceedingly rich mines of the country have been partially worked only for the last twenty years. Several companies are mining gold at La Guayra, and the most important of these is the Callao, which, in 1885, exported 1,730,712 ounces of gold, representing a value of about $34,000,000. We may mention also the English copper mine company of Arva, which, in 1886, exported nearly $600,000 worth of ore.

The following are the statistics of Venezuela for 1886 :

Population	2,198,320	
Railways in operation	139	miles.
" constructing	244	"
" projected	1,200	"
Telegraphs	2,507	"
Agricultural products	$10,600,000	
Live stock	1,520,000	
Mining products	5,712,000	
Importations	12,490,675	
Exportations	16,460,856	
Coast trade	11,716,251	

Let us add that the commercial movement was effected by means of 9,263 ships—7,568 Venezuelan, 212 French, etc.

Like its South American neighbors, Venezuela has concentrated its entire exhibit in a special pavilion located on the Champs de Mars, between the Eiffel tower and the Palace of Liberal Arts.



PAVILION OF THE UNITED STATES OF VENEZUELA AT THE PARIS EXHIBITION.

The pavilion was constructed by Mr. Paulin, a French architect. As Venezuela has no national architecture, Mr. Paulin borrowed from the principal characters of the architecture called the "Spanish Renaissance;" so that the little bottle-shaped dome and the *motifs* of the frontons and platbands upon a facade of uniform whiteness recall the palaces and public buildings of Granada and Seville, the construction of which dates from the reign of Charles V.

The structure, which occupies an area of about 4,800 square feet, comprises a main building and two wings. The main building comprises, at the entrance, a *salon* of honor, followed by a wide *patio* with internal colonnade, and ends in a gallery whose central part forms a *loggia*. In the wing to the left, a small saloon forms the ground floor, and a turret staircase gives access to a small belvedere. The wing to the right, which is covered with a sort of tent, breaks, through its varied tones, the uniformity of the colors of the two other parts of the structure.

The exhibition was organized by General Guzman Blanco and a committee of which Commissary-General Para-Bolivar is president.

The products exhibited belong to six different groups, and are divided into twenty-four classes. They consist of perfumery, basket work, hats, fans, cotton fabrics, silk and hemp fabrics, Indian bridles, beautiful mineral specimens, gold, silver, copper, and iron ores, coal, gums, resins, varnishes, birds of rare plumage, fruits, barks, rubber, gutta percha, cotton, seeds and medicinal plants, tiger and other skins, mineral waters, food products, such as rice, wheat flour, tea, coffee, etc.

There is one special hall in the pavilion reserved for the science of anthropology, and this certainly is not the least interesting part of the exhibition. It constitutes a history of the Paches and Guarranos, the Indians who shared the country with each other before the conquest. We find here not only their skeletons, skulls, and detached bones, but also their costumes, armor, and hunting and fishing implements; two sarcophagi, one of them of bark and containing a corpse; and, finally, a facsimile of one of the hills that form the pre-Colombian necropolis discovered in 1887 by Mr. V. Marcano.—*Abstract from Le Genie Civil.*

THE ARGENTINE REPUBLIC AT THE EXPOSITION.

Through the extent of its territory, its situation, and its agricultural and industrial wealth, the Argentine Republic occupies in South America a rank, so to speak, that belongs to the United States in the north, and it is now possible to foresee the important role that it is to play in the world in the twentieth century.

Its increasing prosperity is so much the more deserving of attracting our attention in that this wonderful country, with which we have so numerous affinities of race and language, a long time ago acquired our ideas, manners, and tastes, in that it has never undergone any other intellectual influence than ours, in that it yearly receives thousands of our compatriots who ask it to employ their hands, their capital, or their knowledge, and, in a word, and without exaggeration, in that it constitutes our finest colony.

The spirit of production which is manifesting itself in the Argentine Republic required more than a simple pavilion on the Champs de Mars for its exhibition, and so it figures there in a true palace, built by Mr. Ballet, architect, and decorated by Duez, Toche and Roll, artists like Tony, Fleury, Gervex, etc.

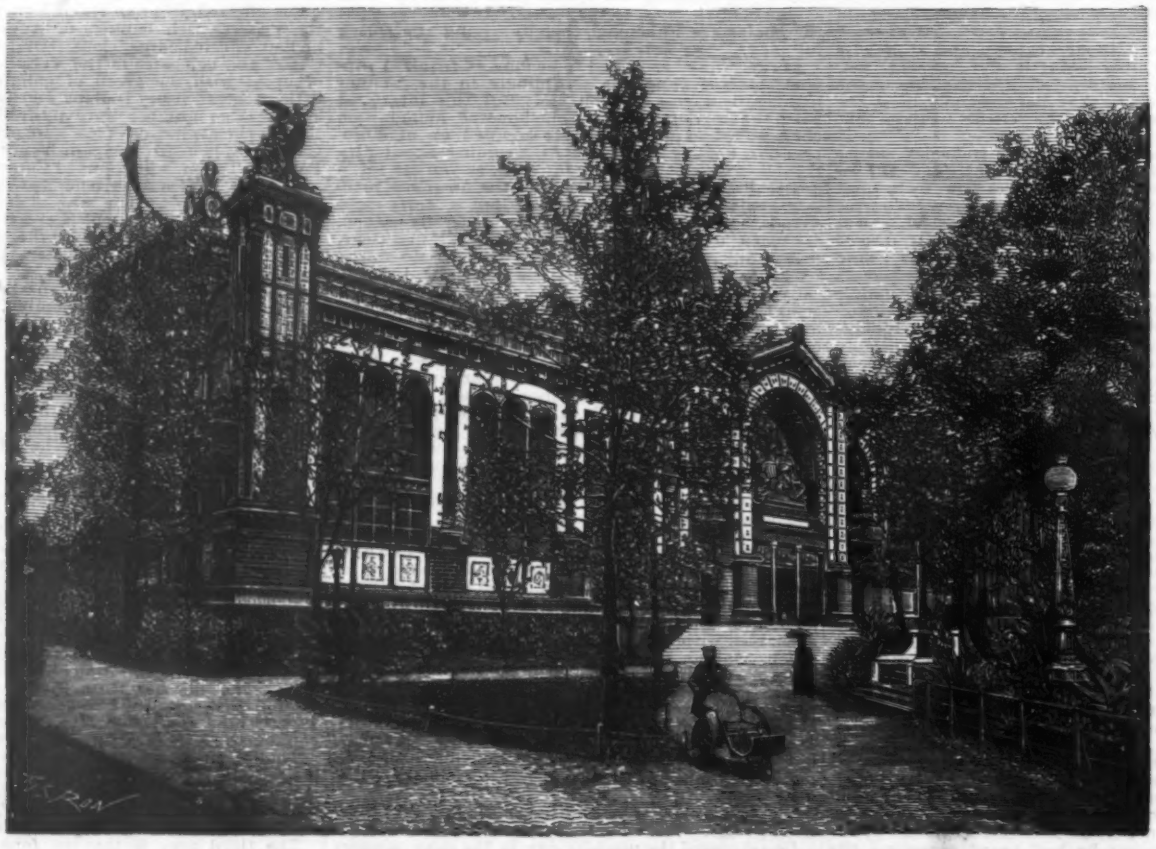
This edifice covers a superficies of 18,275 square feet, and consists of a main building surmounted with a central dome 92 feet in height, flanked with four cupolas 73 feet in height, and with two symmetrical wings to the right and left. In the axis of the entrance there is a staircase that leads to the galleries of the first story. The framework, which is entirely of iron, is decorated with pretty polychrome terra cottas furnished by Mr. Emile Muller, with glass windows of a new system, with mosaics, and with polished crystal glass bull's eyes lighted by electric lamps that form 900 luminous points, producing a magnificent effect. Decorative sculptures crown the four corner towers and the main entrance, and ornament the pendentives of the large cupola.

This structure cost no less than $280,000. It is to be taken down and rebuilt at Buenos Ayres, where it will serve as an exhibition palace, as the Palace of Industry does at Paris.

We now propose to give some precise data regarding the objects exhibited and the economic situation of this country, whose market is daily increasing and may become an important center of exportation for our products.

The fundamental phenomenon of the development of the Argentine Republic is immigration. The government makes every effort to favor the tide of immigration, and, for that purpose, spends no less than $1,500,000 per annum. So, in twenty-five years, the population has increased by 150 per cent., and to-day is 4,500,000 inhabitants. There is nothing to surprise us in such a progression when we reflect that 120,000 immigrants, on an average, yearly land at Buenos Ayres. With the increase of the population, the land fit for culture was soon under tillage.

Yet a very detailed map in relief, to be seen at the entrance of the Argentine pavilion, shows immense stretches which, despite recent progress, still await the



THE PAVILION OF THE ARGENTINE REPUBLIC AT THE PARIS EXHIBITION.

work of man to yield to him the riches that they contain.

In 1852, land in the province of Buenos Ayres was not worth more than 48 cents an acre. To-day, within a radius of 13 miles around Buenos Ayres, the bare land, generally occupied by French Basques, is sold at from $64 to $80 per acre. In the region of the farms, that is to say, within a circumference of 50 miles radius passing through Buenos Ayres, land is granted at a price varying from $32 to $64 per acre.

Beyond, save near the southern and eastern railway lines, farming has given way almost entirely to raising stock, especially sheep. Pasture land is rented at $500 per square mile, and the selling price is $5,900.

In 1887, in the territory of Chaco, 200 miles from Buenos Ayres, the government sold at public auction, at $700 per square mile, land that would not have found buyers at 12 cents an acre twenty-five years ago. In a general way, it may be said that to-day, in the entire republic, there are no longer any lands worth less than $590 per square mile.

The figures just given show that the source of the national wealth is, and will be for a long time to come, agriculture and the raising of cattle. So the products of agriculture and live stock raising are largely represented in the Argentine exhibit.

As soon as we cross the threshold of the main entrance, we remark to the left a reproduction of a chamber serving for the preservation of meat by cold, which was installed by the Sansinena Society of Buenos Ayres. This, for most of the visitors, is a novelty that never fails to attract their attention.

The importation of cooked meats, preserved by the Appert process, has never had much success in Europe, since such food cannot replace fresh meat, although it is valuable in certain cases. As for the importation of living animals from a distance, say from Australia or La Plata, that has not been any more fortunate, because of the cost of carriage and of feeding on board, and of the mortality during the passage.

It was the French of Basque origin who first foresaw the service that the exportation of frozen meat might render to France and England. To-day, there are four frigorific establishments for the preservation of mutton, the only meat that the Argentine Republic can now deliver to our markets. In 1888, the exportation of frozen mutton was 40,145,573 pounds. In the two months of January and February, 1889, England alone imported 151,884 frozen sheep from the Argentine Republic.

The animals are taken by short trips from the breeding centers, and inclosed in vast pasture grounds at the ports of Buenos Ayres, where they wait to be slaughtered. As soon as the sheep have been slaughtered, their carcasses are placed in cold chambers, where they are gradually frozen. From the establishments of Buenos Ayres, the meat is transferred to cold chambers on shipboard in which a constant temperature of —12° is maintained through the simple expansion of compressed air. Upon reaching Europe, the meat is deposited in cold chambers analogous to those in Buenos Ayres, and whence they are shipped to market on special cars.

In the galleries of the first story of the Argentine palace, we find a remarkable collection of wools, due to the initiative of the Buenos Ayres Chamber of Commerce. These wools are derived from the shearings of 1886, 1887, and 1888, and comprise specimens of all the varieties found in the province of Buenos Ayres, from the poorest and coarsest to the richest and finest.

The largest yield of wool is furnished by animals crossed with the Rambouillet race of sheep.

The wool production of the republic is 350,000 bales of about 880 pounds each.

The exportation in 1887 was 240,263,642 pounds, of which the official value was $32,749,315, and that of 1888 reached 289,835,347 pounds, valued at $44,858,608.

The wool exhibit is completed by that of leathers and skins, the exportation of which to Europe is likewise one of the chief elements of the commerce of the republic.

In 1888, there were exported 61,705,745 pounds of sheep skins, valued at $2,608,013, and 57,403,372 pounds of cow and calf skins, valued at $10,045,967.

The agricultural products are represented by very numerous specimens. According to the official publications of the Bureau of Statistics, the number of acres devoted to the culture of wheat was, in 1888, 1,500,000.

Allowing a product of $\frac{4}{10}$ of a ton to the acre, the entire amount would have been 600,000 tons.

The quantity exported the same year was 393,602,000 pounds—a diminution of 129,703,025 pounds upon the preceding year.

After the culture of wheat comes that of Indian corn—to which 965,000 acres are devoted. Granting the normal product to be 2,200 pounds to the acre, the entire amount would be a million tons. The quantity exported in 1888 was 358,045,097 pounds—a deficit of 444,012,373 pounds as compared with the shipments of 1887.

The exportation of flax in 1888 dropped to 88,490,352 pounds, a little less than half that of the preceding year. These diminutions in the exports of agricultural products must be attributed to the poor crop of 1887.

Among the new cultures introduced into the republic are those of the olive tree and ramie. The sugar cane is largely cultivated in the province of Tuenman, where there are thirty-eight works devoted to the manufacture of sugar.

The republic's exhibit comprises an entire class devoted to wines derived from the provinces of Mendoza, San Juan, Entre Rios, Salta, and Buenos Ayres. The attempts at viticulture in this favored country have given most encouraging results, and the importations of foreign wines have greatly diminished.

Another industry, which is still in an embryo state, but which will soon make progress with the development of railroads, is that of mining, which is daily discovering new resources over a larger number of points of the Argentine territory. The numerous collections exhibited in the galleries of the first story by the University of Cordova leave no doubt as to the mineral wealth of the soil of the Argentine Republic, and the export figures already allow it to be seen that a brilliant future is in store for it in this regard.

Railroads, those powerful agents of the economic transformation of a country, have been greatly developed in the republic. In one of the galleries of the first story, there is a map of the various systems which teaches us that the Argentine territory in 1887 was provided with 15 lines, of a total length of 4,515 miles, with a traffic of 8,210,255 passengers and 3,962,651 tons of merchandise.

In 1887 alone, 17 new lines were conceded by the government, 13 of them with a guarantee of 5 per cent. These guaranteed lines represent a length of 4,471 miles, and the 4 others, 1,963 miles. In 1888, the government refused all guarantees, and granted concessions only with numerous restrictions; yet 11 lines were constructed that increased the total by 1,800 miles.

The government, while actively developing its railway system, has also devoted large sums of money to the improvement of its ports. The city of Buenos Ayres, the largest commercial center of South America, is soon to have four ports, which altogether will give 15 miles of canals and 21 miles of wharfs. They will comprise the old port—that of Riachuelo, which can now, owing to the dredging of the channel, be entered by ships of the largest tonnage; the port of Madero, which is now constructing, but one basin of which is open to commerce; the southern docks, which will be situated opposite port Madero; and finally, the city port, the project of which has recently been presented by Commodore Lasserre.

Buenos Ayres is therefore destined to become one of the most important commercial places of the world, as shown, moreover, by the increasing progress of its maritime affairs.

It now remains to show that, in the way of intellectual progress, the Argentine Republic has displayed as much activity as it has in material progress. The number of pupils in attendance at the schools of all kinds, public and private, is 227,450. In 1883, the number was 146,325. There are now 2,712 public schools—216 in the province of Buenos Ayres, 233 in Santa Fe, and 147 in Cordova—the three most thickly settled provinces. The city of Buenos Ayres has 24 high schools, 56 primary schools, 20 infant schools, and 16 schools for adults, which give instruction to 27,209 pupils. The instruction of each pupil costs, on an average, $30 per year. There are, besides, 132 private schools in Buenos Ayres and 635 in other cities. The number of teachers employed in the public schools is 3,579—1,611 of them men and 1,968 women.

The higher instruction is given in the two universities of Buenos Ayres and Cordova, and professional instruction in the schools of agriculture of Mendoza, in the school of arts and trades of Santa Catalina, and the military school of Buenos Ayres.

We shall terminate with a glance at the financial situation of the republic. This appears to be very satisfactory, judging from official documents. The high value of the lands and city property, the increase of commerce, the founding of new banks, and the extension of capital and credit are the causes of the increase of public revenues that permit the treasury to respond to the exigences of all the services.

In 1886, the revenue of the nation was $40,762,000, and in 1887, $58,135,000. The figures for 1888 are wanting, but there is every reason to believe that they will exceed $70,000,000.

The consolidated public debt, internal and external, was, on March 31, 1888, $139,527,000.

According to official statements, the public debt can be extinguished in eight years, with the product of the public lands, the reserves of gold deposited in the national bank and in those belonging to the state, the 180,000 shares of the national bank, which are the property of the state, and the revenues from different public works—the whole amounting to a sum greater than that of the debt.

On another hand, the depreciation and fluctuation of bank notes constitutes an exceedingly grave misfortune for the republic, and is a source of anxiety to the public powers. Speculation in specie is carried on to a large extent, and gold is now at a premium of 57 per cent. In order to remedy this state of things, the minister of finances is this year to propose to Congress the adoption of the bimetallic system, to the foundation of which $40,000,000 in gold would be appropriated in order to replace the emission of small bank notes with copper, silver, and gold coin.

The holder of guaranteed bills would be able to exchange them at par for silver specie coined upon the basis of the Latin union, and selling his silver money like ingots, he would be then subject to a loss of but from 20 to 25 per cent. It is evident that it would be advantageous to make such a change, so long as the premium on gold was greater than the loss experienced.—*Abstract from Le Genie Civil.*

PAVILION OF SAN SALVADOR AT THE PARIS EXHIBITION.

PAVILION OF THE REPUBLIC OF SALVADOR.

THE government of the republic of Salvador confided to Mr. E. Pector, its consul-general, the authority of installing its exhibition on the Champ de Mars, and Mr. Pector employed Mr. J. Lequeux, an architect of Paris, to get up the plans for the pavilion and to superintend and direct the building of it. The external aspect of the structure is pleasing, as a whole, and presents a well elaborated outline. There is but one thing to be regretted, and that is that it is not set far back enough to allow one to obtain from any one point a general view of it. The relative quiet of the pavilion is broken by a decoration which is somewhat peculiar,

and which, to many visitors, will remain a genuine mystery. It was borrowed from the history of Mexico. The *faience motifs* are composed of the signs of the Mexican years, of the eighteen months that form the year, and of the twenty days that make up the month. Finally, a frieze represents the Mexican kings.—*La Semaine des Constructeurs.*

EXPERIMENTS UPON THE TRANSMISSION OF POWER BY COMPRESSED AIR IN PARIS (POPP'S SYSTEM).*

By Alexander B. W. Kennedy, F.R.S., M. Inst. C.E., Emeritus Professor of Engineering and Mechanical Technology in University College, London.

The subject of transmission of power to a distance is one of such immense importance in an industrial country like our own that I am sure I need offer no apology for bringing this paper before Section G of the British Association. In a case such as that which I have to describe to you, where the distance to which the power is to be transmitted is great enough to be measured in miles, the possible methods of transmission are not very numerous. Steam, water, air, and electricity seem to be the only four agents practically available. All four have been used to a greater or less extent, and with more or less complete success. In our own country the distribution and use of high pressure water has been carried out with the greatest engineering skill and with correspondingly great success by the Hydraulic Power Company in London, and also in Hull.

Electric transmission (for traction at least) has been at work on a small scale for some time in various places, and is about to be tried on a much larger scale under Mr. Greathead on the Southwark Subway. In America it has been very widely used for traction on tramways, and on the Continent it has also been used to a certain extent for power transmission for general purposes. Steam has been used on a large scale in New York, but as yet its success does not seem to be unquestionable. Compressed air has, of course, been used over and over again in rough and uneconomical fashion in connection with tunneling and boring work, but I think only two practical attempts have been made to utilize it economically and on a large scale for industrial purposes. Of these two, one has been made in Birmingham and the other in Paris. The Birmingham Compressed Air Power Company has established works on a very large scale, but various causes have unfortunately combined to cause delay in the commencement of its operations, which indeed are hardly yet fairly started. In Paris, however, the transmission of power by compressed air has been in operation on a somewhat large scale and with very great mechanical success for a few years past.

I have recently had occasion to spend some weeks in making experiments in connection with the Paris compressed air plant, and having been given the fullest permission to publish the results of my experiments, I have pleasure in taking this opportunity of bringing them before the members of the British Association. To avoid any misunderstanding I must premise that it is not my intention to institute any comparison between the different methods of power transmission which I have mentioned. Such a comparison, to be of any value, would require for itself a paper at least as long as the one which I have to put before you, and is, therefore, in the nature of things impossible here. On this matter I wish to say only one thing, in view of a recent discussion on the Hydraulic Power Company's work in London, in which some comparisons were made between power transmission by air and by water. So far as I see, the two systems at present practically occupy different fields, and overlap but little. The work that each appears to do best is exactly that for which the other is least fitted. I see as little chance for air, just now, taking the place of water for lifts or cranes, as I do for water coming into common use in driving of motors.

I think it would be a pity if there were to be any impression that two systems were antagonistic which, in point of fact, rather supplement each other. Having said this much, it will, I think, be my most useful and most interesting course to limit myself to a description of the plant and methods used in Paris, and to a statement of the actual results obtained there, as determined by my own experiments on the spot. The plant and methods are by no means absolutely perfect; they are not only susceptible of, but are now receiving, considerable improvements in detail in the extensions which are being carried out. In what I have to say, however, I shall confine myself entirely to results actually obtained with the present plant, as it was working when I tested it two months ago, not giving it credit for the result of any of the improvements which have not yet been introduced throughout into the system of working. I shall only, after having given this statement of facts, state briefly my views as to the probable practical value of improvements which may be, or are being, carried out.

The work now carried on by the Paris Compressed Air Company has developed from very small beginnings, at first slowly, lately very fast. It originated in a pneumatic clock system, which was started about 1870 with a small "central station" in the Rue St. Anne, in the center of Paris. This business grew gradually until it became far too large to be carried on from such a position, and a few years since a central station, with much enlarged machinery, was established in the Rue St. Fargeau, which is in Belleville, about 4½ miles east of the Madeleine.

There are now about 8,000 pneumatic clocks, public and private, in Paris, driven from St. Fargeau, and regulated by a standard clock in the Rue St. Anne; but as this part of the work, although it originally formed the basis of the whole system, is now a comparatively very small part of it, and is of an entirely special nature, I do not propose to say anything further about it here.

Until about two years since, a pair of single cylinder horizontal engines by Farcot, and a beam engine by Case, sufficed for the whole work, but by that time the demand for compressed air for working motors had so increased that extension had become imperative, and the present working plant of six compound condensing engines, each working two air compressors, with the necessary complement of boilers, was put down. This plant, except the compressors, was supplied from England by Messrs. Davey, Paxman & Co., of Colchester. The compressors for the English engines were made in Switzerland on the Blanchod system. The demand for power is at present so great that, at certain hours of the day, practically the whole plant, old and new, indicating considerably over 2,000 horse power, is fully at work, and in consequence a duplicate main is being laid throughout, and new engines and compressors, half of them constructed by Davey, Paxman & Co. and half by John Cockerill & Co., of Seraing, are being pushed forward as rapidly as possible.

The general system of working is illustrated roughly by the sketch diagram, Fig. 1, which of course is in no

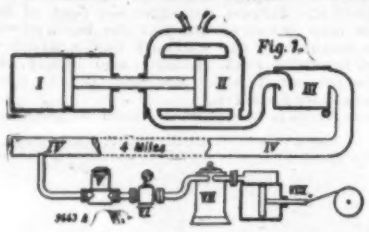


Fig. 1.

way drawn to scale, and it is as follows: The steam cylinders, I, compress the air to a pressure of five atmospheres (six atmospheres absolute) or thereabout in the compressor cylinders, II. The air is drawn in direct from the engine house, where I found it to be about 70 deg. Fahr., and after it has finally passed along the mains for some little distance it is again about the same temperature. It is, therefore, of the greatest importance to prevent its temperature rising during the compression, as all heat so taken up by the air represents work done in the steam cylinders of which no part whatever can be utilized. If the air were compressed adiabatically, *i. e.*, without any cooling whatever, its temperature on leaving the compressor would be about 430 deg. Fahr.—a temperature higher than that of saturated steam of 300 lb. per square inch pressure. At St. Fargeau water for cooling is allowed to run into the cylinders through the suction valve, during the suction stroke, in such quantity that the final temperature is only 150 deg. Fahr. So far the result is satisfactory enough, but owing, unfortunately, to the particular way in which the cooling water is utilized mechanically, the air does not get cooled until after it has been compressed, so that practically no benefit is obtained from the cooling, in spite of the extent to which it occurs. The power expended, as we shall see presently, is practically equal to what would have been expended had the compression been adiabatic. The quantity of air dealt with at each revolution is 47·6 cubic feet (for the pair of double-acting compressing cylinders), which is equivalent to 3·55 lb., the quantity of water used being about 2·4 lb.

After compression, the air, now having an absolute pressure of six atmospheres and a temperature of 150 deg. Fahr., is pushed into large boiler plate receivers (III), of which some are arranged to act as separators, and in these a large portion of the cooling water, which has been carried along mechanically by the air, is deposited and removed, before the air enters the mains, IV. The principal main is 300 mm. (11·8 in.) in diameter and about ⅜ in. thick. It is of cast iron, made in lengths perfectly plain at each end, and connected by a very simple external joint made air tight by India rubber packing rings. This joint leaves the pipe quite free endwise, and also allows all necessary sideway freedom, so that accidental distortion to a quite measurable extent is entirely without effect on the tightness of the joint. The mains are partly laid under roadways and footways as they would be in this country and partly slung from the roof of the sewer subways. They are supplied at intervals with automatic float traps for carrying off the entrained water and the water of saturation, as they deposit.

On entering a building on its way to a motor, the air is first passed through a meter (V) exactly as gas would be. The quantity passing is of course too great to allow anything like an ordinary gas meter to be used; indeed, only inferential meters seem to have been at all successful. The meter actually in use in Paris is a small double cylindrical box. The air passes by a branch through to the bottom of the inner box, up through it, down outside it between the two boxes, and away through a branch at the bottom opposite the inlet branch.

The whole measuring apparatus is a little four or six armed fan, with aluminum or nickel vanes, placed near the bottom of the inner casing and communicating motion by a light vertical steel spindle to a clockwork register, like that of a gas meter, placed on the top. The quantity recorded is simply the number of revolutions made by the fan, or some proportional number, and this is turned into cubic meters by multiplication by an arbitrary constant, determined by direct experiment. As to the working of this meter I shall have something to say later on; it is the only type used by the Paris company, and serves in a very large number of cases as basis of payment.

After passing the meter the air is carried through a reducing valve (VI), by which the initial pressure in the motor is prevented from rising above a certain limit, which in practice appears to vary between 3½ and 5½ atmospheres absolute, according to the size of the motor in proportion to its work.

Between the reducing valve, VI, and the motor, VIII, there is placed in all ordinary cases a small stove or heater, VII. This heater is simply a double cylindrical box of cast iron, having an air space between its outer and its inner walls. The air under pressure traverses this space, and is compelled, by suitably arranged baffle plates, to circulate through it in such a fashion as to come into contact with its whole surface. A coke fire is lit in the interior of the stove, and the products of combustion are carried over the top of it, and made to pass downward over its exterior surface, inside a sheet iron casing, on their way to the chimney flue. The heater for the motor on which I experimented (which indicated 10 to 12 horse power) was about 21 in. in diameter and 2 ft. 9 in. high over all. The use of the heater, and the extent to which that use is advantageous and economical, are matters on which I shall touch later.

The motors themselves (VIII) used in Paris are mainly of two types. Up to one horse power or thereabout small rotary engines, of a form patented by M. Popp, are used; into the details of these it is not necessary to enter here. They start very readily, are easily governed, are provided with capital automatic lubricators worked by compressed air, run at a very high speed, and are altogether very convenient. They use the air with little or no expansion, without previous heating, and have, of course, no pretense to economy in use of air.

The larger sized motors, up to double-cylinder engines 12 in. by 14 in., which is the largest size used, are simply ordinary Davey-Paxman steam engines, employed for air absolutely without any alteration or modification. These engines have, in most cases, automatic cut-off gear controlled by the governor, and can, therefore, easily work with the largest economical ratio of expansion for the not very high available initial pressure. I believe that in every case heaters are provided for these engines, although in some instances, where both power and refrigeration are required, they are used sparingly or not at all, in order to take advantage of the cooling due to expansion.

After this short description of the general arrangements of the Paris company's work I come now to the experiments which I made to ascertain its efficiency. Starting from the main engines at the central station, the particular matter which I had to determine was the indicated horse power which would be shown by a small motor three or four miles from St. Fargeau for each indicated horse power expended by the main engines on the air which passed through that motor. The ratio thus obtained would be the total indicated efficiency of the whole system of transmission. This ratio is in reality the product of a number of separate efficiencies, and the separate determination of these formed a necessary check on the value of the total efficiency. These separate efficiencies may be summarized as follows:

1. Mechanical efficiency of main engines, or ratio of work done in compressors to indicated work in steam cylinders.
2. Efficiency of compressors, or ratio of maximum work which could be done in a motor by each cubic foot of compressed air at 70 deg. Fahr. to the work actually done in compressing that air.
3. Efficiency of mains, or ratio in which the capacity of the compressed air for doing work is reduced by friction and leakage.
4. Efficiency of reducing valves, or ratio in which the capacity of the compressed air for doing work is reduced by the lowering of its initial pressure at the motor.
5. Indicated efficiency of motor, or ratio in which the actual indicated work done falls short of the maximum work which the quantity of air measured through the meter could do after passing the reducing valve.

The product of these five efficiencies is the total efficiency of transmission without the use of a heater. When a heater is used, the matter is somewhat more complicated. All the ratios given above represent what may be called mechanical efficiencies, all of them have *unity* for their maximum attainable value. It is, therefore, not possible to introduce in direct combination with them a thermodynamic efficiency (ratio of additional heat supplied to additional work done) which has for its maximum value, not unity, but 0·3 or some similar small value. This could only be done if the measurement of efficiency had started originally from the heat given to the steam instead of from the indicated horse power, and this would have given numbers having a minimum of practical value or convenience. Probably the best practical measure of the efficiency of the whole transmission, when using heated air, is obtained by finding the equivalent in indicated horse power at the central station of the coke used in the heater, and adding this to the indicated horse power actually used. It would not be possible, by the expenditure of this or any other amount of indicated horse power at the central station, to obtain the same results as by heating the air just before entering the motor, but that, of course, does not affect the question before us.

The determination of the indicated horse power of the main engines presented no difficulty. I measured it on one pair of engines at different speeds from 21 to 44 revolutions per minute. At 31·5 revolutions per minute it amounted to 254·9, and at all speeds it was approximately 8·1 indicated horse power per revolution per minute. The mechanical efficiency was sensibly the same at all speeds, viz., 84·5 per cent., as given in the table. There was no method available for ascertaining to what extent the real quantity of air delivered corresponded to the nominal volume swept through by the compressor pistons. The indicator diagrams (Fig. 2) show no signs of leakage past the valve, but there are no doubt various possible leakages which would not show on the diagrams. In the absence of any direct means of determination, however, I have assumed that the compressor cylinders delivered their full volume, which corresponds to 348 cubic feet* of air per indicated horse power per hour. This air has a weight of about 25 lb. It may be pointed out that the water injected practically fills up the clearance space at the end of each stroke.

I have already pointed out that at whatever temperature the air is delivered, it must fall to about its original temperature in the long length of mains before it reaches the motors. It is, therefore, a simple matter to find the maximum amount of work which can be done by the air delivered per indicated horse power, for it simply amounts to the P V of the air at six atmospheres absolute and at 70° Fahr., plus the work it can do in expanding adiabatically to a pressure of one atmosphere, and minus the work necessary to expel it from the cylinder at that pressure and at the corresponding temperature.†

In the present case I find that this work is equiva-

* British Association: Newcastle meeting, 1889. *Engineering.*

* Here and elsewhere, unless specially mentioned, volumes are supposed to be at atmospheric pressure and at 70 deg. Fahr., the actual admission temperature during my experiments.

† In symbols, if suffixes 1 and 2 be used for the initial and final conditions of the air, if pressures be measured in pounds per square foot and volumes in cubic feet, the maximum work possible, without addition of heat, is

$$(P_1V_1-P_2V_2)\frac{\gamma}{\gamma-1}=3{\cdot}45\,(P_1V_1-P_2V_2)$$

lent to 0·52 indicated horse power for an hour, so that the efficiency of the compressors is, as given in table, 61 per cent.

It will be seen from the diagrams that the compression curve falls only a little below the adiabatic, and as the area of the diagram is increased somewhat by the resistance of the discharge valve, the work done is practically the same as if the compression had been adiabatic, and there had been no cooling at all. This matter I have already referred to.

Fig. 3 shows graphically the relation between the quantities so far measured. If the area, A B C D E, represents on any scale the work done in the steam cylinder, the area, A B C F, represents on the same scale the work done on the air in the compressors. C B is an adiabatic curve, C G a hyperbola, so that A G represents the volume of the compressed air when it has fallen in the mains to the temperature which it had initially at C. G H being again an adiabatic curve, the area A G H F (which is 61 per cent. of A B C F, and 52 per cent. of A B C D E) represents the maximum work which can be obtained from the air in a motor, the quantity calculated in the last paragraph.

If it be assumed that the temperature in the mains is constant, then any loss of pressure, due to friction, must be accompanied by an exactly equivalent increase of volume.

Thus if (Fig. 3) the pressure falls from A to K, the volume increases from A G to K L, the point, L, lying on an isothermal through G. The loss of possible work due to such a reduction of pressure is represented by the difference between the areas A G H F and K L M F, in both of which the expansion curves are adiabatic. The change of temperature in passing through a reducing valve is so small that it may be assumed without sensible error that the loss due to such a process may be calculated in the same fashion.

I determined the loss of head in the mains by a series of observations made simultaneously at known points in Paris and at St. Fargeau. The pressure gauges used having been carefully compared, and all the necessary corrections made, I found the loss of pressure to vary from 0·35 to 0·25 atmosphere, according to the distance from St. Fargeau and the amount of air passing through the pipes.

The average loss may be taken as 0·3 of an atmosphere at three miles from St. Fargeau, when the indicated horse power there was about 1,250 and the maximum velocity of the air in the mains about 1,550 feet per minute. What proportion of this loss of head may have been due to leakage, and what the amount of leakage (if any) may have been, I had no means of determining.

The duplicate main to which I have referred is not yet completed, and it was impossible to isolate any portion of the mains, even temporarily, to test for leakage. From the figures I have given, as well as from the nature of the pipe joint, I cannot doubt that the leakage must, under any circumstances, have been extremely small.

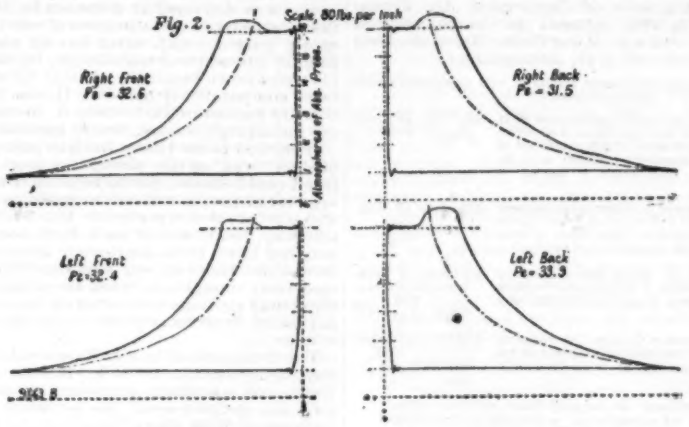
In the table I have given approximate values of the loss due to falt of pressure in the mains and through the reducing valve, with various values of the total reduction of pressure. With a total reduction of half an atmosphere the combined efficiency of mains and valves is 0·96, reducing the maximum possible work at the motor to 0·5 indicated horse power per indicated horse power at central station. Under these conditions the minimum possible consumption of air per indicated horse power at the motor would be twice 348, or 696 cubic feet per hour.

The motor on which I made most of my experiments was an ordinary horizontal Davey-Paxman engine, with a single cylinder 8¼ inches in diameter and 12 in. stroke, fitted with automatic cut-off gear. For convenience sake I tested it at St. Fargeau and not in Paris, but I used a pressure only of 4½ atmospheres, which pressure I found to be exceeded on branch mains 3½ miles from St. Fargeau, where I made later experiments. The position of the motor did not, therefore, put it under any conditions different from those existing in the center of Paris.

I made a large number of experiments on this motor, under various conditions, individual experiments lasting from four hours down to half an hour. I shall here give figures representing only the four most important of my experiments, two with cold and two with heated air, averaging the two experiments in each case, so as not to burden my paper with unnecessary figures.

The motor, when indicating 9·9 horse power, and making about 125 revolutions per minute, used 890 cubic feet of air per indicated horse power per hour. (Its indicator diagrams are shown in Fig. 4, their area being represented by K N O in Fig. 3.)

The work which this quantity of air, at a given pressure and temperature, is theoretically capable of doing behind a piston, expanding down to atmospheric pressure, is equivalent to 1·27 horse power for an hour. The indicated efficiency of the motor (the ratio expressing loss by rounding of curves, by insufficient expansion, by back pressure, etc.) is therefore 0·79. This figure gives us a check on the ratios already worked out, for if they are right, the air actually used should be $\frac{1}{0·79}$ times as great as the 696 cubic feet already allowed for. This would be 880 cubic feet, which represents, of course, a most satisfactory check.



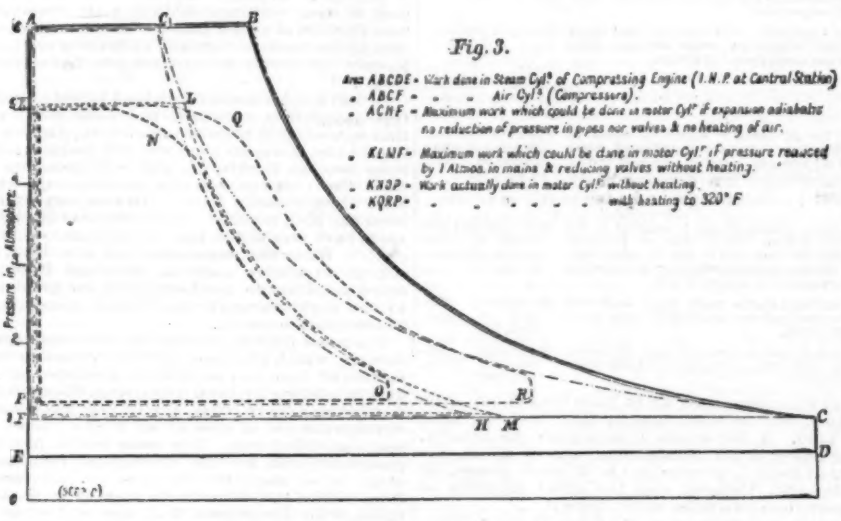
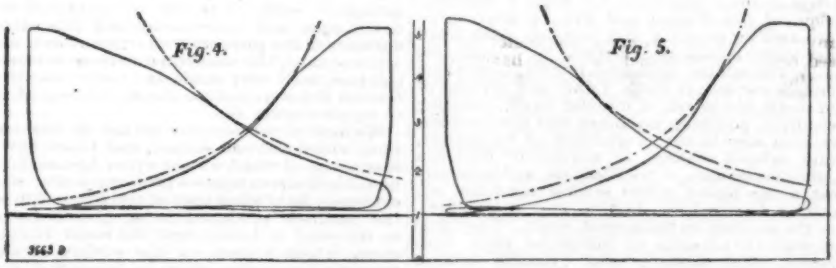


Fig. 3.
Area ABCDE = Work done in Steam Cyl.s of Compressing Engine (I.H.P. at Central Station)
" ABCF = " " Air Cyl.s (Compressors).
" ACHF = Maximum work which could be done in motor Cyl.r if expansion adiabatic no reduction of pressure in pipes nor valves & no heating of air.
" KLMF = Maximum work which could be done in motor Cyl.r if pressure reduced by 1 Atmos. in mains & reducing valves without heating.
" KNOP = Work actually done in motor Cyl.r without heating.
" KQRP = " " " " " with heating to 320° F
Pressure in Atmospheres
A
C1
B
G
L
Q
N
H
M
C
F
K
R
D
E



It will, however, be recognized that this agreement checks the figures only so far as they apply to air actually used, and would not be vitiated or in any way affected by losses by leakage.

The vital measurement of all the experiments was, of course, that of the quantity of air used. The air was passed through one of the fan meters already described, readings of which were taken every quarter of an hour. After the experiments were over, air was passed through the same meter at exactly the same pressure, and in as nearly as possible the same quantity, and then passed, at atmospheric pressure, through two large standard wet gas meters. The readings of these were taken as correct, and the multiplier for the fan meter determined from them.

I found from numerous experiments on several fan meters that this multiplier varied both with pressure and with quantity, but that the latter variation was very small within the limits of my experiments. I have no doubt that the air quantities which I shall give you are correct within about 2 per cent. plus or minus.

It will be seen that the total indicated efficiency of transmission with cold air is 0·39 (see table); in other words, that work requires to be done at the rate of 2·6 indicated horse power at the central station per indicated horse power at the motor. The motor was worked on a brake, and its mechanical efficiency was found to be 0·67, so that (see table) in round numbers 4 indicated horse power were required at St. Fargeau per brake horse power at the motor.

To examine the economy due to heating the air before using it, I used the same motor, working as nearly as possible at the same power and speed and with exactly the same pressure, but passing the air between the meter and the engine through such a heating stove as I have already described. I weighed all the coke used, and read the temperatures every five minutes during a four hours' trial. The air was heated in passing through the stove up to 315° Fahr., with a consumption of about 0·39 lb. coke per indicated horse power per hour.

As the admission temperature on the cold trials was 83° Fahr.* only, this corresponds to an increase of about 42 per cent. in the volume of the air, and should, therefore (had the indicated efficiency remained the same), have been accompanied by a decrease of air consumption in the ratio $\frac{1}{1·42}$ or 0·70. The air actually used was 665 cubic feet per indicated horse power per hour, which is 0·75 of the 890 cubic feet formerly required, so that the full economy is very nearly realized.

The indicator diagrams are shown in Fig. 5, and are represented by K P Q O in Fig. 3. An air consumption of 665 cubic feet per indicated horse power per hour corresponds to an indicated efficiency over the whole system of 0·52; in other words, 1·92 indicated horse power is required at St. Fargeau per indicated horse power at the motor.

The mechanical efficiency of the motor was very much greater hot than cold, rising to 0·81. Hence about 2¼ indicated horse power at St. Fargeau gave 1 brake horse power at the motor.

These figures, however, take no account of the coke burnt in the heater, and are, therefore, only to be considered as *apparent* efficiencies. Allowing for the value of the coke in the manner already described, the real indicated efficiency of the whole transmission is 0·47.

A shorter experiment with slightly higher temperatures and considerably larger indicated horse power gave still more economical results, the air consumption falling to 623 cubic feet per indicated horse power per hour, an "apparent" indicated efficiency of 0·56. This experiment was not, however, of sufficient duration to allow of coke measurement.

As to the value of the preliminary heating, the figures which I have given show that it caused a saving of 225 cubic feet of air per indicated horse power per hour, at a cost to the consumer of about 0·4 lb. of coke per indicated horse power per hour.

I do not doubt that the stoking of the heater during my experiment was much more careful than it would be in ordinary practice, although, on the other hand, it would not be difficult to design a more economical stove. If, however, the coke consumption were even doubled, it would only amount to 72 lb. per day of nine hours for 10 indicated horse power, the value of which might be 6d. or 7d.

The air saved under the same circumstances would be over 20,000 cubic feet, the cost of which, at the high rate charged in Paris, would be 7s. 3d.

There is no doubt, therefore, that to attain the maximum of economy the preliminary heating of the air should be carried as far as is practicable.

Of course heating the air serves the purpose also of preventing any chance of the exhaust pipe becoming ice-clogged. I found this to happen once or twice when working with cold air, its occurrence depending rather on the amount of moisture in the air than on the exhaust temperature, for the engine, after running freely with an exhaust of —35° Fahr., choked later on at + 2° Fahr.

I do not think that in any case which I met with there would have been any trouble from choking had the exhaust pipes been properly arranged. As it was, they were merely the ordinary vertical exhaust pipes of a steam engine, quite suitable for their original and for their intended purpose, but singularly unfitted for the purpose to which I was putting them.

Summarizing now the whole matter as regards efficiency, it may be said that the result of my detailed investigations is to show that the compressed air transmission system in Paris is now being carried on on a large commercial scale in such a fashion that a small motor four miles away from the central station can indicate in round numbers 10 horse power for 20 indicated horse power at the station itself, allowing for the value of the coke used in heating the air, or for 25 indicated horse power if the air be not heated at all.

Larger motors than the one I tested (and there are a number of such in Paris) may work somewhat more, and smaller motors somewhat less, economically.

The small rotary motors would, of course, be much less economical. The figures which I have given are, however, such as can be reached by any motor of be-

* This somewhat high admission temperature was the only point in which the motor at St. Fargeau differed from those in Paris, where I found the admission temperature to be from 60° to 71° Fahr.

tween 5 and 25 indicated horse power if worked at a fair power for its size

M. Victor Popp himself, and the engineers of the company, by no means content with the results already obtained, are experimenting in various directions with a view to greater economy, and I have not the least doubt that they will attain their end. But although I made several experiments on new apparatus, I prefer to leave their results here undiscussed, confining myself as strictly as possible to the work which has been already carried out and the economy of actual present working, rather than giving any credit for the result of improvements, which, however certain they may be thought, are not yet actually carried out in practical work.

A system of transmission which has actually been carried out on a large commercial scale in such a way as to have an indicated efficiency of 50 per cent. between prime mover and secondary motor, four or five miles apart, is one which needs no adventitious aids to commend it to notice, especially where its uses are so numerous and so varied, and its convenience so extremely great, as are those of compressed air.

Both M. Victor Popp, who has organized and carried through the work of the Paris company, and Mr. James Paxman, who has designed and made the greater part of the machinery used, are to be heartily congratulated on the results which have attended their work.

While, however, I am unwilling to lay stress on possibilities which are not yet actualities, there can be no harm in saying that I have no doubt whatever that with mere improvement of existing methods and appliances, and without the adoption of any new or untried methods whatever, the new plant of the Paris company now being constructed can be made to have an indicated efficiency of 67 per cent. instead of 50 per cent., and to give about 0·54 effective horse power at the motor for each indicated horse power at the central station, in the case of such a motor as that on which I experimented.

Under these circumstances the air used per indicated horse power at the motor would be 520 cubic feet, or 650 cubic feet per brake horse power. I have the less hesitation in given these hypothetical figures because the more important imperfections of M. Popp's transmission system arise from such a very obvious cause. Nothing, indeed, can be easier (as was evident on the recent visit of the Institution of Mechanical Engineers to St. Fargeau) than to point out various weak points in the arrangements adopted, and yet, in spite of all such somewhat cheap criticism, the fact remains that no one has yet carried out a compressed air transmission with anything approaching to the same success on anything like the same scale. The fact is that the success of the system has been essentially due rather to the practical good sense with which the work has been carried through than to any special novelty in the methods employed.

The air-compressing arrangements at St. Fargeau are in no respects novel or specially perfect, they had been used over and over again before; there is no special advantage in M. Popp's rotary motor that may not probably be possessed by many other rotary motors; the larger motors are simply good ordinary steam engines such as can be bought any day in open market, used without the slightest alteration.

Of the fan meter it can only be said that it works well enough to allow progress to be made while it is being improved, and even of the coke stove one would not like to say very much more.

The plan of heating compressed air before using it in a motor was first proposed many years ago. The great success which has attended the work in Paris has been attained because its directors have wisely chosen rather to set to work with imperfect apparatus, if only it were simple, fairly effective, and ready to hand, than to wait for the possible invention of novelties and improvements, or to risk the success of their start by the use of any unknown or untried apparatus, however promising its nature. They had, moreover, the great advantage hitherto of being always asked for more air than they could supply, so that their works have grown and increased simply to meet a growing and increasing demand, and (fortunately, perhaps) the urgency of the demand has left them no alternative but to meet it by the very simplest possible means.

I have already mentioned the great convenience and handiness which a compressed air motor possesses. From the engineer's point of view these qualities are most striking. The engine starts, for instance, without the least hesitation even with full brake load on, directly the valve is opened, if the crank is just past the center. This, of course, is impossible with a gas engine, and hardly less impossible with any ordinary (single-cylinder) steam engine.

The absence of the heat and leakage, and of the noise and smell, which so often in greater or less degree accompany the smaller steam or gas motors, constitute a very much larger difference than could at first be thought possible. But from the consumer's point of view the advantages are even greater than from the engineer's. There is, first of all, the complete absence of danger and of nuisance of every kind. There is then the great saving of space, even as compared with a gas engine, and much more as compared with a steam engine and boiler. There is reduction of insurance on account of the entire absence of fire risk. Not only this, but the air motor seems to me completely to supply that most important industrial want, a motor suitable for "small industries," that is, for work carried on in workmen's own houses or in very small workshops. For here it is not only mechanically most suitable, but in the nature of things it can be made to cool or ventilate, by its exhaust, to any desired extent. The sanitary advantage of this, in cases where work is carried on in confined spaces, can hardly be exaggerated.

Even in a very large printing office in Paris I found an almost unbearable atmosphere made quite pleasant as long as the motor was working, by allowing a portion of the exhaust to come into the room.

By using air direct from the mains in the motor, or by heating it only very slightly, the exhaust air can be, of course, so greatly reduced in temperature as to be available for freezing purposes.

In one Paris restaurant, for instance, which I visited, I found that the exhaust was carried through a brick flue into the beer cellar. In this flue the carafes were set to freeze, and large moulds of block ice were also being made for table use, while the air was still cold enough in passing away through the beer cellar to render the use of ice for cooling quite unnecessary, even in the hottest weather.

The nominal function of the engine in this case was the charging of batteries used in the electric lighting of the restaurant. The conjoint use of power and cold is common in Paris, the power being in this case generally applied in electric lighting.

While in any large city, such as Paris, it is no doubt a great point that by a compressed air system the handiest possible cooling appliances can be brought everywhere within reach, in tropical climates this is something rather of necessity than of luxury. In such cases we might have the apparent paradox of a motor worked essentially for its exhaust; the work done would be a by-product, the cold air would be the principal thing.

In such a case, if there were no useful work to be done, the motor could even be made (as has been suggested to me) to pump air back into the main, and thus virtually to about halve its air consumption. This possibility of "laying on" cold air in hot climates is, of course, a most important matter in connection with the future of compressed air.

TABLE.

Summary of Efficiencies of Compressed Air Transmission at Paris, 1889, *between the Central Station at St. Fargeau and a 10 Horse Power Motor working with Pressure reduced to 4½ Atmospheres.*

(The figures below correspond to mean results of two experiments cold and two heated.)

1 indicated horse power at central station gives 0·845 indicated horse power in compressors, and corresponds to the compression of 348 cubic feet of air per hour from atmospheric pressure to 6 atmospheres absolute. (The weight of this air is about 25 lb.)	Efficiency of main engines 0·845.
0·845 indicated horse power in compressors delivers as much air as will do 0·52 indicated horse power in adiabatic expansion after it has fallen in temperature to the normal temperature of the mains.	Efficiency of compressors $\frac{0·52}{0·845}$ = 0·61.
The fall of pressure in mains between central station and Paris (say 5 kilometers) reduces the possibility of work from 0·52 to 0·51 indicated horse power.	Efficiency of transmission through mains $\frac{0·51}{0·52}$ = 0·98
The further fall of pressure through the reducing valve to 4½ atmospheres (5½ atmospheres absolute) reduces the possibility of work from 0·51 to 0·50.	Efficiency of reducing valve $\frac{0·50}{0·51}$ = 0·98.
The combined efficiency of the mains and reducing valve, between 5 and 4½ atmospheres, is thus 0·98 × 0·98 = 0·96. If the reduction had been to 4, 3½, or 3 atmospheres, the corresponding efficiencies would have been 0·92, 0·89, and 0·85 respectively.	
Incomplete expansion, wire drawing, and other such causes reduce the actual indicated horse power of the motor from 0·50 to 0·39.	Indicated efficiency of motor $\frac{0·39}{0·50}$ = 0·78. Indicated efficiency of whole process with cold air 0·39.
By heating the air before it enters the motor to about 320° Fahr., the actual indicated horse power at the motor is, however, increased to 0·54. The ratio of gain by heating the air is, therefore, $\frac{0·54}{0·39}$ = 1·38.	Apparent indicated efficiency of whole process with heated air, 0·54.
In this process additional heat is supplied by the combustion of about 0·39 lb. coke per indicated horse power per hour, and if this be taken into account the real indicated efficiency of the whole process becomes 0·47 instead of 0·54.	Real indicated efficiency of whole process with heated air, 0·47.
Working with cold air the work spent in driving the motor itself reduces the available horse power from 0·39 to 0·26.	Mechanical efficiency of motor, cold, 0·67.
Working with heated air the work spent in driving the motor itself reduces the available horse power from 0·54 to 0·44.	Mechanical efficiency of motor, hot, 0·81.

Most of the compressed air in Paris is used for driving motors, but the work done by these is of the most varied kind. A list which I have gives the locality, use, and power of 225 installations, nearly all motors working at from ½ horse power to 50 horse power, all driven from St. Fargeau, and the great majority of them more than two miles away from it.

In a number of cases (as at the Eden Theater, Theater des Varietes, office of the *Petit Journal*, etc.) the motor drives dynamo machines for electric lighting. In the offices of the *Figaro* and *Petit Journal* large motors are used for printing, and there are many small printing establishments also worked by compressed air. Among the smaller industrial purposes for which the air motors are used in Paris, I find the driving of lathes for metal and wood, of circular saws, shearing machines, drills, polishing machines, and many others. They are used also in the workshops of carpenters, joiners and cabinet makers, of smiths, of umbrella makers, of collar makers, of bookbinders, and naturally in a great many places where sewing machines are used, both by dressmakers, tailors, and shoemakers, and from the smallest to the largest scale. They find application also in all sorts of industrial work, with confectioners, coffee roasters, color grinders, billiard ball makers, in many departments of textile industry and other matters too numerous to mention.

I may mention one particular instance of variety of application which interested me much. At the "Montagnes Russes" I found a large horizontal engine placed in a recess driving a dynamo and cells for the electric lighting of the whole building; a small vertical engine in another place worked the rotary pump which actuated the "cascade;" two or three large air-driven fans in wooden shafts served for ventilation; and lastly, a simple connection on a flexible pipe threw the air pressure into the beer barrels as they were brought in, and transferred their contents to a height from which they could afterward descend by gravity to the place where they were required.

As to the rate at which the compressed air is sold, I believe that in most of the larger installations the work is done by contract (at so much per lamp hour in the case of the electric lighting), but in the smaller ones the air is charged for by meter. The rate of charge is 1·5 centimes per cubic meter for air used in motors and 2 centimes cubic meter for air used directly. Air used for raising fluids is charged according to quantity raised. The former rate is equivalent to 4·25d. per 1,000 cubic feet (the volume in all cases being measured at atmospheric pressure).

In addition to this a fixed charge of from 100 to 250 francs is made for pipes and connections, and a small rent for the motor, if it be not bought outright.

In conclusion, I have to express my thanks to M. Victor Popp and to the directors and officials of the Paris Compressed Air Company for not only giving me permission to make the experiments of which I have laid some results before you, but also for taking much trouble to afford me every facility for making a thorough investigation of the matter upon the lines which I had myself laid down as those along which I proposed to work.

I think it is not too much to say that, as the result of this, I have had the good fortune to be able to make a more detailed and complete evaluation of all the efficiencies which together make (or mar) the efficiency of a complete transmission system than has ever been made before. I shall be very glad if my experiments prove in any way useful to those who in future may have to do with the carrying out of power transmission by compressed air in this country or elsewhere.

ON THE HARDENING AND TEMPERING OF STEEL.*

By Professor W. C. Roberts-Austen, F.R.S.

The fact that the British Association meets this year at Newcastle no doubt suggested to the council that it would be well to provide, for the first time since 1848, a lecture on a metallurgical subject. In that year a discourse was delivered at Swansea by Dr. Percy, one of the most learned metallurgists of our time, who has recently passed away, after having almost created an English literature of metallurgy, by the publication of his well-known treatises, without which it would have been comparatively barren. It was to him that the country turned in 1851, when it became evident that our metallurgists must receive scientific training.

It seemed to me that "the hardening and tempering of steel" was, on the whole, the most important subject I could choose, partly because it will enable a large number of people who are engaged in industrial work, and who are not expected to think about it in a scientific way, to know how such facts as we shall have to consider have been dealt with by scientific investigators, while those of our members who do not consider that their thoughts or work are scientific in its strictest sense may perhaps be interested to see how absolutely industrial progress depends upon the advancement of science.

The treatment of iron in its several forms is the thing that we as a nation do well. If it be true that national virtues are manifestly expressed in the industrial art of a people, we may recall the sentence in Mr. Ruskin's "Crown of Wild Olive" in which he says, "You have at present in England only one art of any consequence, that is iron working," adding, with reference to the manufacture of armor plate, "Do you think on those iron plates your courage and endurance are not written forever, not merely with an iron pen, but on iron parchment?"

In 1863 Lord Armstrong, in his address as president of this Association, expressed the hope that "when the time again comes round to receive the British Association in this town, its members will find the interval to have been as fruitful as the corresponding period," since the previous meeting in 1838, "on which they were then looking back." In one way at least this hope has been realized, for the efforts of the last twenty years have resulted in the development of an "age of steel." When the Association last met here, steel was still an expensive material, although Bessemer had, seven years before, communicated his great invention to the world through the British Association, at its Cheltenham meeting.

The great future in store for Siemens' regenerative furnace, which plays so important a part in the manufacture of steel, was confidently predicted in his presidential address by Lord Armstrong, than whom no one was better able to judge, for no one has done more to develop the use of steel of all kinds. Steel, we shall see, is modified iron. The name iron is, in fact, a comprehensive one, for the mechanical behavior of the metal is so singularly changed by influences acting from within and without its mass as to lead many to think, with Paracelsus, that iron and steel must be two distinct metals, their properities being so different. Pure iron may be prepared in a form pliable and soft as copper; steel can readily be made sufficiently hard to cut glass, and notwithstanding this extraordinary variance in the physical properties of iron and certain kinds of steel, the chemical difference between them is comparatively very small, and would hardly secure attention if it were not for the importance of the results to which it gives rise.

We have to consider the nature of the transformations which iron can sustain, and to see how it differs from steel, of which an old writer has said, "Its most useful and advantageous property is that of becoming extremely hard when ignited and plunged in cold water, the hardness produced being greater in proportion as the steel is hotter and the water is colder. The colors which appear on the surface of steel slowly treated direct the artist in tempering or reducing the hardness of steel to any determinate standard." There is still so much confusion between the words "temper," "tempering," and "hardening," in the writings of even very eminent authorities, that it is well to keep these old definitions carefully in mind. I shall employ the word tempering in the sense of softening, as Falstaff uses it when he says of Shallow, "I have him already tempering between my finger and my thumb, and shortly will I seal with him:" softening, that is, as brittle wax does by the application of gentle heat. Hardening, then, is the result of rapidly cooling a strongly heated mass of steel. Tempering consists in reheating the hardened steel to a temperature far short of that to which it was raised before hardening; this heating may or may not be followed by rapid cooling. Annealing consists in heating the mass to a temperature higher than that used for tempering, and allowing it to cool slowly.

First let the prominent facts be demonstrated experimentally: Three sword blades of identical quality made by an eminent swordsmith, Mr. Wilkinson, were taken. It was shown by bending one that it was soft; this was heated to redness and plunged in cold water, when it became so hard that it broke on the attempt to bend it. Another was bent into a bow, the arc of which was four inches shorter than the sword itself, a

* Abstract of a lecture delivered on September 13 before the members of the British Association, Newcastle, 1889.

common test for "temper," and it sprang back to a straight line when the bending force was removed; this had been tempered. A third, which had been softened by being cooled slowly, bent easily and remained distorted.

The metal has been singularly altered in its properties by comparatively simple treatment, and all these changes, it must be remembered, have been produced in a solid metal to which nothing has been added and from which nothing material has been taken. The operation of hardening steel which I have just conducted is practiced daily in thousands of workshops, and the details of the process are so well known that it may, at first sight, seem unnecessary to devote a lecture to the subject. The theory of the operation has been laboriously built up, and its consideration introduces many questions of great interest both in the history of science and in our knowledge of molecular physics.

Now for the history of the subject. The knowledge that steel might be hardened must have come to us from remote antiquity. Copper hardened with tin was its only predecessor, and it continued to be used very long after it was known that steel might be hardened. It would, moreover, appear that a desire to appreciate the difficulties of a people to whom cutting instruments of hard steel were unknown seems to have induced experimenters in quite recent times to fashion implements of bronze, and a trustworthy authority tells us that "Sir Francis Chantry formed an alloy containing about 16 parts of copper, 2½ of zinc, and 2½ of tin, of which he had a razor made, and I believe even shaved with it."

The Greek alchemical MSS. which have been so carefully examined by M. Bertholet give various receipts from which it is evident that in the early days the nature of the quenching fluid was considered to be all-important. There were certain rivers, the waters of which were supposed to be specially efficacious. Pliny, who says that the difference between the waters of various rivers can be recognized by workers in steel, also knew that oil might be used with advantage for hardening certain varieties of the metal. It is sad to think how many of the old receipts for hardening and tempering have been lost.

What would we not give, for instance, for the records of the Gallic prototype of our Iron and Steel Institute, the *Collegium fabrorum ferrariorum*, a similar guild, formed in the time of the Roman republic for the advancement of knowledge, for the good of the state, and not for that of its individual members? The belief, however, in the efficacy of cūrious nostrums and solutions for hardening steel could hardly have been firmer in the third century B.C. than in the sixteenth of our era. Shakespeare suggests that Othello's sword had been hardened in a cold stream, for he says that it had "the ice brook's temper;" but cold water was far too simple a material for many a sixteenth century artificer to employ, as is shown by the quaint receipts contained in one of the earliest books of trade secrets, which, by its title, showed the existence of the belief that the "right use of alchemy" was to bring chemical knowledge to bear upon industry.

The earliest edition was published in 1531, and the first English translation in 1583, from which the following extracts may be of interest: "Take snayles, and first draw water of a red die of which water being taken in the two first monthes of harvest when it raynes," boil it with the snails, "then take your iron red hot and quench it therein and it shall be hard as steell." "Ye may do the like with the blood of a man of XXX years of age and of a sanguine complexion, being of a merry nature and pleasant . . . . distilled in the middst of May." This may seem trivial enough, but the belief in the efficacy of such solutions survived into the present century, for I find in a work published in 1809 that the artist is prettily directed to take the root of blue lilies, infuse it in wine and quench the steel in it, and the steel will be very hard; on the other hand, he is told that if he "takes the juice or water of common beans and quenches iron or steel in it, it will be soft as lead."

I am at a loss to explain the confusion which has arisen from this source. I have dwelt so long on these points in order to bring out clearly the fact that the early workers attached great importance to the nature of the fluid in which hot steel was quenched, and they were right, though their theories may have been wrong. The degree of rapidity with which heat is abstracted from the steel during the operation of hardening is as important at the present day as it ever was. Roughly speaking, if steel has to be made glass hard, ice cold water, brine, or mercury is used; if it has only to be made slightly hard, hot water or oil may be employed, while, as Thomas Gill suggested in 1818, both "hardening" and "tempering" may be united in a single operation by plunging the hot metal in a bath of molten lead or other suitable metal, which will, of course, abstract the heat more slowly.

We must now trace the development of theories relating to the internal constitution of steel. It seems as if the whole history of chemical science was epitomized in the history of our knowledge of the nature of steel. The old "sulphur and salt" view of the composition of bodies was most ingeniously applied to steel by Reaumur in 1722, who considered that hardened steel owes its rigidity to the driving out of sulphurs and salts from the molecules of iron into the interstitial spaces between them, the molecules becoming firmly fixed by the rapid cooling of the mass; on the other hand, in tempered steel, the sulphurs and salts had time, during the slow reheating, to re-enter the molecules, the mass thereby becoming comparatively soft. The believers in phlogiston thought that steel merely differed from iron by containing more phlogiston, but Torbern Bergman, in 1781, the great professor of Upsala, himself a firm believer in phlogiston, showed that steel merely differs from iron by containing a few tenths per cent. of carbon; he unfortunately confounded the plumbago or graphite he had isolated from steel with phlogiston, and the defense of his view brought down the entire strength of the French school and elicited a reply from Taissier himself. This was almost the last resolute phlogistic fight.

Black, not unnaturally, thought that the hardening of steel was due to the "evolution of latent heat," the abatement of the hardening by tempering being due, he says, to "the restoration of a portion of this heat." Black failed to see that Bergman, by proving that carbon was the element which converted iron into steel, had entirely changed the situation. The next step was made in France. It was considered necessary to establish the fact that carbon gives steel its characteristic properties, and with this object in view Clouet, in 1798, melted together pure iron and a diamond. His experiments were repeated by many observers, but the results were open to doubt from the fact that furnace gases could always obtain access to the iron, and might, as well as the diamond, have yielded carbon to the iron. The question was, however, solved in this country in 1815 by a working cutler, M. Pepys, who heated iron wire and diamond dust together and obtained steel, the heat being afforded by a powerful electric battery. I am anxious to make this absorption of carbon in the diamond form clear by experiment. Do not think for a moment that the steel owes its hardness to the passage of diamond into the iron as diamond. I have repeated Pepys' experiment exactly, and the result is shown in a diagram.

Hempel has shown that in an atmosphere of nitrogen, iron appears to assimilate the diamond form of carbon more readily than either the graphitic or the amorphous forms, but directly carbon is associated with molten iron it behaves like the protean element it is, and the state which this carbon assumes is influenced by the rate of cooling of the molten mass, or even by the thermal treatment to which the solidified mass is subjected. Let me repeat, all are familiar with carbon in the distinct forms of diamond, graphite, and soot—all are alike carbon. It need not be considered strange, then, that carbon should be capable of being present in intimate association with iron, but in very varied forms.

Now the mode of existence of carbon in soft annealed steel is very different from that in which it occurs in hard steel. I believe that Karsten was the first to isolate, in 1827, from soft steel a true compound of iron and carbon. Berthier also separated from soft steel a carbide of iron to which he assigned the formula FeC; but to attempt to trace the history of the work in this direction would demand an entire lecture. I will only add that within the last few years Sir F. Abel has given much experimental evidence in favor of the existence in soft cold-rolled steel of a carbide, Fe_3C, which he isolated by the slow solvent action of a chromic acid solution. His work has been generally accepted as conclusive, and has been the starting point of much that has followed.

It will occur to you that the microscope should reveal wide differences between the structure of the various kinds of iron and steel, and I am happy to be able to give you enlarged diagrams made from the drawings of Mr. Sorby, the eminent microscopist, which illustrated his very delicate investigations into the structure of steel.

The point I am mainly concerned with is the existence of a substance which Sorby called the "pearly constituent" in soft steel. This pearly constituent is the carbide of iron, Fe_3C, of Abel.

Now we may fairly ask, does the existence of carbon in iron in these two different states of carbide or combined carbon and dissolved or hardening carbon sufficiently explain the main facts of hardening and tempering? It does not. It is possible to obtain by rapid cooling from a certain temperature steel which is perfectly soft, although analysis proves that the carbon is present in the form which we have recognized as hardening carbon. No doubt in the hardening of steel the carbon changes its mode of existence, but we must seek some other theory to explain all the facts, and in order to do this, we will turn to the behavior of the iron itself.

It is universally accepted that metals, like all the elements, are composed of atoms of definite weights and volumes grouped in molecules. In order actually to transmute one metal into another it would be necessary to discover a method of attacking, not the molecule, but the atom, and changing it, and this, so far as it is known, has not yet been done, but it is possible, by influences which often appear to be very slight, to change the relations of the molecules to each other, and to alter the arrangements of distribution of the atoms within the molecules, and by varying in this sense the molecular arrangement of certain elements, they may be made to pass into states which are very different from those in which we ordinarily know them. Carbon, for instance, when free, or when associated with iron, may readily be changed from its diamond form to the graphitic state, though the converse change has not as yet been effected.

Sulphur, again, with which you are familiar as a hard brittle yellow solid, may be prepared and maintained for a little time in the form of a brown viscous mass, but the latter form of sulphur soon passes spontaneously and slowly at the ordinary temperature, and instantaneously at 100 deg., to the solid octahedral yellow modification with evolution of heat. The viscous form of sulphur is an allotropic modification of sulphur. A few cases of allotropy in metals have already been established, and when they do occur they give rise to problems of vast industrial importance. Such molecular changes in metals are usually produced by the addition of a small quantity of foreign matter, and I have elsewhere tried to show that the molecular change produced by the action of traces upon masses is a widespread principle of nature, and one which was recognized at the dawn of the science of chemistry even in the seventh century, but distorted explanations were given of well known facts, and gave rise to entirely false hopes. But it is the same story now as in mediæval times; the single grain of powder which Raymond Sully said would transmute millions of its weight of lead into gold; the single grain of stone that Solomon Trismosin thought would secure perpetual youth, had their analogues in the small amount of plumbago which, to Bergman's astonishment, in the eighteenth century, converted iron into steel. By this time it was recognized that the right use of alchemy consisted in the application of its methods to industry, and we still wonder at the minuteness of the quantity of certain elements which can profoundly affect the properties of metal.

In attempting to illustrate this part of the subject, I cannot take the most striking cases, as it is difficult to demonstrate them in the time at my disposal. The following experiment, which does not, however, depend upon the action of a trace upon a mass, will enable me to lead up to the point I wish to insist upon. It consists in the release of gold from its alloy with potassium. When the alloy is treated with water, the gold comes down in a finely divided, dark brown, chemically active state.

I have chosen this experiment because it was a similar one that first roused suspicion that pure iron could exist in more than one form.

So far as I have been able to ascertain, Joule supplied the first link in the chain of evidence. He showed, in a paper communicated to the British Association in 1850, that iron released from its amalgam with mercury, by distilling away the mercury, is chemically active, and will take fire in air, and he claimed that it was a distinct form of iron, but he did more; he suggested that a thermo-electric method would enable the difference between soft and hardened steel to be studied, and, as I shall hope to show, his view has been abundantly justified. The next step was made in Russia 1868, by Chernoff, who has found an admirable exponent to English readers in Mr. W. Anderson, president of section G. Chernoff showed that steel could not be hardened by rapid cooling until it had been heated to a definite temperature, to a degree of redness which he called *a*. Then in 1873 Professor Tait used this expression in a Rede lecture at Cambridge: "It seems as if iron becomes as it were a different metal on being raised above a certain temperature. This may possibly have some connection with the ferricum and ferrosum of the chemist." At about this time those specially interested in this question remembered that Gore had shown that a curious molecular change could be produced by heating an iron wire. Barrett repeated Gore's experiment, and discovered that as an iron wire cools down it suddenly glows, a phenomenon to which he gave the name of recalescence. In 1879 Wrightson called attention to the abormal expansion of carburized iron at high temperatures; and finally, within the last few years, Piouchon showed that at a temperature of 700 deg., the specific heat of iron is altogether exceptional, and Le Chatelier has detected that at 700 deg. a change occurs in the curve representing the electromotive force of iron, both experimenters concluding that they had obtained evidence of the passage of iron into an allotropic state.

Osmond, in France, then made the observations of Gore and Barrett the starting point of a fresh inquiry, bearing in mind the fact that molecular change in a body is always accompanied with evolution or absorption of heat, which is the surest indication of the occurrence of molecular change; he studied with the aid of a chronograph the cooling of masses of iron or steel, using as a thermometer to measure the temperature of the cooling mass a thermo-electric couple such as we have here of platinum, containing 10 per cent. of rhodium, converting the indications of the galvanometer into temperatures by Tait's formulæ.

[NOTE.—It is impossible to describe this portion of the lecture without the aid of the illustrative diagrams, curves, and experiments. Professor Austen dwelt specially on the researches of Osmond, to which he said he attached great importance, as he considered that Osmond had given strong experimental evidence in favor of the view that iron can exist in two distinct molecular states. The argument was presented in the following way:]

Now, it may be urged, evidently the presence of carbon has an influence on the cooling of steel when left to itself. May it not affect molecular behavior during the rapid cooling which is essential to the operation of hardening? We know that the carbon, during rapid cooling, passes from the state in which it is combined with the iron into a state in which it is dissolved in the iron; we also know that during slow cooling this dissolved carbon can re-enter into combination with the iron, so as to assume the form in which it occurs in soft steel. Osmond claims that this second arrestation in the fall of the thermometer corresponds to the recalescence of Barrett, and is caused by the reheating of the wire by the heat evolved when carbon leaves its state of solution and truly combines with the iron.

If it is hoped to harden steel, it must clearly be rapidly cooled before this combination of carbon and iron has taken place, or it will be too late to keep the carbon as hardening carbon. Osmond argues thus: There are two kinds of iron, the atoms of which are respectively arranged in the molecules so as to constitute hard and soft iron, quite apart from the presence or absence of carbon. In red hot iron the mass may be soft, but the molecules are hard. Let us call this β iron; cool such red hot pure iron, whether quickly or slowly, and it becomes soft; it passes to the α soft modification. There is nothing to prevent it doing so. It appears, however, that if carbon is present and the metal be rapidly cooled the following result is obtained. A certain proportion of the molecules are retained in the form in which they existed at a high temperature, the hard form, the β modification, and hard steel is the result. This molecular change from β iron to α iron during the slow cooling of a mass of iron or steel is, according to Osmond's theory, indicated by the first break in the curve, representing the slow cooling of iron, as is proved by the fact that it occurs alone in electro-iron. A second break, usually one of much longer duration, marks the point at which carbon itself changes from the dissolved or hardening carbon to the combined carbide carbon. It follows that if steel be quickly cooled after the change from β to α has taken place, but before the carbon has altered its state, that is before the change indicated by the second break in the curve has been reached, then the iron should be soft, but the carbon, hardening carbon, and as such the action of a solvent should show that it cannot be released from iron in the black carbide form. This proves to be the case, and affords strong incidental proof of the correctness of the view that two modifications of iron can exist. I am anxious to show you an experiment which will help to illustrate the existence of molecular change in iron.

Here is a bar of steel containing much carbon. In such a variety of steel, the molecular change of the iron itself, and the change in the relations between the carbon and the iron, would occur at nearly the same moment. It is now being heated to redness, but if you will look at this diagram, you will be prepared for what I want you to see in the actual experiment. One end of the red hot bar is firmly fixed, a weight not sufficient to bend it is slung to the free end, which is lengthened by the addition of a reed to magnify any motion that may take place. Now remember that as the bar will be red hot it ought to be at its softest, you would think, when it is freshly withdrawn from the furnace, and if the weight was ever to have power to bend it, it would be then, but, in spite of the rapid-

ity with which such a thin bar cools down in the air and becomes rigid, points of molecular weakness come when the iron changes from β to α, and the carbon passes from hardening carbon to carbide carbon. At that moment, at a temperature much below that at which it is withdrawn from the furnace, the bar will begin to bend. It has been found experimentally that this is the point at which, according to Osmond's theory, molecular change takes place. Mr. Coffin takes advantage of this fact to straighten distorted steel axles.

The question now arises, what is the effect of the presence of other metals in steel, of which much has been heard recently? 1. Manganese. This metal enables steel to harden very energetically, as is very well known. If much of it be present, 12 to 20 per cent., in iron, no break whatever is observed in the curve which represents slow cooling. That is, the iron never shows such a change as that which occurs in other cooling masses of iron. Then you will say such a material should be hard, however it is cooled. So it is. There is one other important point of evidence as to molecular change connected with the addition of manganese to submit to you. Red hot iron is not magnetic. Hopkinson has shown that the temperature of recalescence is that at which iron ceases to be magnetic. It may be urged that iron cannot, therefore, be magnetized. Steel containing much manganese cannot be magnetized, and it is therefore fair to assume that the iron present is in the β form. Hadfield has given metallurgists wonderful alloys of iron and manganese in proportions varying from 7 to 20 per cent. of manganese.

This core of iron round which a current is passing attracts the sphere of iron, but if nothing is changed except by replacing the core of iron with a core of Hadfield's steel, it is impossible to make a magnet of it.

Professor Ewing, who has specially worked on this subject, concludes that "no magnetizing force to which the metal is likely to be subjected in any of its practical applications would produce more than the most infinitesimal degree of magnetization" in this material. It has been seen that quantities of manganese above 7 per cent. appear to prevent the passage of β iron into the α form. In smaller quantities manganese seems merely to retard the conversion and to bring the two loops of the diagram nearer together. Time will not permit me to deal with the effect of other elements on steel. I will only add that tungsten possesses the same property as manganese, but in a more marked degree.

Chromium has exactly the reverse effect, as it enables the change of hard b iron to α soft iron to take place at a higher temperature than would otherwise be the case, and this may explain the extreme hardness of chromium steels when hardened in the same way as ordinary steels.

[Note.—The researches of Chernoff and of Brinell were here dealt with, and special care was devoted to the influence of oil hardening on large masses of steel. This portion of the lecture does not, however, admit of being abstracted without the illustrations.]

Now, although wrought iron passes almost insensibly into steel, there can be no question that not merely the structural but the molecular aggregation of even steel containing only 0·2 per cent. of carbon is profoundly different from that of wrought iron. Formerly, as Sir F. Braunwell pointed out in a lecture delivered at the Royal Institution in 1877, by the year 1830 . . . . . "from small beginnings in Staffordshire and at Birkenhead sprang a wonderful wrought iron navy." But steel was a luxury; it was made in small portions, sold at high prices—as much as a shilling or eighteen pence a pound. It was employed for swords, cutlery, and tools, needles, and other purposes where the quantity used was but trifling, and where the importance of the superior material was such as to justify the large expenditure incurred. It was felt in those days that steel was worth paying for because it was trusted; indeed, its trustworthiness had passed into a proverb—"as true as steel."

The class of steel which was formerly employed as I have just indicated, for weapons and tools, belonged to the highly carburized, readily hardening class. It was the "mild steel," containing but little carbon, which was destined to replace wrought iron, and when attempts were made to effect the general substitution of steel for iron, doubts to its character and trustworthiness unfortunately soon arose, so that from about the year 1860 until 1877 steel was viewed with suspicion. We can now explain this. Doubts as to the fidelity of steel, even when it was obtained free from entangled cinder, arose from ignorance of the fact that on either side of a comparatively narrow thermal boundary iron in steel can practically exist in two distinct modifications. The steel was true enough, but from the point of view of the special duties to be intrusted to it, its fidelity depended on which modification of iron had to be called to the front. Artificers attemped to forge steel after it had cooled down below the point α of Chernoff, at which recalescence occurs, and they often attempted to work highly carbonized steel at temperatures which were not sufficiently low.

Steels may be classified from the point of view of their industrial use according to the amount of carbon they contain, and I have attempted to arrange in this trophy certain typical articles grouped under certain definite percentages of carbon. Each class merges into the other, but the members at either end of the series vary very greatly. It would be impossible to make a razor which would cut of boiler plate, and conversely, a boiler plate made of razor steel would possibly fracture at once if it were superheated and subjected to any sudden pressure of steam.

At the present day, instead of steel being manufactured and used in small quantities, about 4,000,000 tons are annually employed in this country. Let us see how it is used. A steel fleet, the finest fleet in the world, has recently assembled at Spithead. The material of which it was made contained 0·15 to 0·2 per cent. of carbon, and when steel faces are used for the armor plates, the material contained 0·7 to 0·8 per cent. of carbon.

It has been pointed out that the crews of the fleet at Spithead number no less than 21,107 men. This, it has been shown, is a "remarkable figure, considering the great economy in men which prevails in a modern navy as compared with the navy of Nelson's day. A hundred years ago the normal requirements of a fleet were one man to a little over four tons, but now, thanks to the part played by steel and hydraulic power, we require but one man to every seventeen tons. Thus it may roughly be said that an aggregate of 20,000 men at the present day corresponds to an aggregate of 80,000 men in the days of Nelson." The latest type of battle ship weighs, fully equipped, about 10,000 tons, there being about 3,400 tons of steel in the hull, apart from her armor, which, with its backing, will weigh a further 2,800 tons.

From the use of steel in the royal navy and in the mercantile marine let us pass to its most notable use in construction. If the president of the French republic was justified in appealing in a recent speech to the Eiffel tower as "a monument of audacity and science," what are we to say of the Forth bridge, the wonders of which will be described by Mr. Baker on Saturday? By his kindness I am able to place in the position in the trophy justified by the carbon it contains, a plate from the Forth bridge, which fell from a height of some 350 ft., and, being of excellent quality, doubled itself on the rocks below. A single span of the Forth bridge is nearly as long as two Eiffel towers turned horizontally and tied together in the middle, and the whole forms a complicated steel structure weighing 15,000 tons, erected without the possibility of any intermediate support, the lace-like fabric of the bridge soaring as high as the top of St. Paul's. The steel of which the compression members of the structure are composed contains 0·23 per cent. of carbon and 0·69 per cent. of manganese. The parts subjected to extension do not contain more than 0·19 per cent. of carbon.

Time will not permit me to pass the members of each class in review. I can only touch upon very few. Steel for the manufacture of pens contains about 0·3 per cent. of carbon, and 16 to 18 tons of steel are every week let loose on an unoffending world in the shape of steel pens.

Steel rails contain from 0·3 to 0·4 per cent. of carbon, and in this class slight variations in the amount of carbon are of vital importance. An eminent authority, Mr. Sandberg, tells us that in certain climates a variation of 0·1 per cent. in the amount of carbon may be very serious. The great benefit which has accrued to the country from the substitution of more durable steel rails for the old wrought iron ones may be gathered from the figures which Mr. Webb, of Crewe, has given me, which show that "the quantity of steel removed from the rails throughout the London and Northwestern system by wear and oxidation is about 15 cwt. an hour, or 18 tons a day."

Gun steel contains 0·3 to 0·5 per cent. of carbon, and it may contain 0·8 per cent. of manganese. It is in relation to gun steel that oil hardening becomes very important. The oil tank of the Saint Chamond works (on the Loire) is 72 ft. deep, and contains 44,000 gallons of oil, which is kept in circulation by rotary pumps, to prevent the oil being unduly heated locally when the heated mass of steel is plunged into it.

Now with regard to projectiles. To quote some recent remarks of Lord Armstrong, "The heaviest shot used in the Victory was 68 lb., while in the Victoria it will be 1,800 lb.; and while the broadside fire from the Victory consumed only 325 lb. of powder, that from the Victoria will consume 3,000 lb." The most formidable projectiles belong to the highly carbonized class of steel. Shells contain 0·8 to 0·94 per cent. of carbon, and in addition some of these have 0·94 to 2 per cent. of chromium. The firm of Holtzer show in the Paris exhibition a shell which pierced a steel plate 10 inches thick and was found nearly 800 yards from the plate entire, and without flaw, its point alone being slightly distorted. Compound armor plate with steel face, which face contains 8 per cent. of carbon, is, however, more difficult to pierce than a simple plate of steel.

Last I will refer to the highly carbonized steel used for the manufacture of dies. Such steel should contain 0·8 to 1 per cent. of carbon and no manganese. It is usual to water-harden and temper them to a straw color, and a really good die will strike 40,000 coins of average dimensions, without being fractured or deformed, but I am safe in saying that if the steel contain 0·1 per cent. too much carbon, it would not strike 100 pieces without cracking, and if it contained 0·2 per cent. too little carbon, it would probably be hopelessly distorted and its engraved surface destroyed in the attempt to strike a single coin.

Faraday said, in 1822, "It is not improbable that there may be other bodies besides charcoal capable of giving to iron the properties of steel." The strange thing is that we do not know with any certainty whether, in the absence of carbon, other elements do play the part of that metalloid, in enabling iron to be hardened by rapid cooling. Take the case of chromium, for instance; chromium-carbon steels can, as is well known, be energetically hardened, but Busek has recently asserted that the addition of chromium to iron in the absence of carbon does not enable the iron to be hardened by rapid cooling.

Every chemist here knows how much his science has gained, and what important discoveries have been made in it, by the recognition of the fact that the elements act on each other in accordance with the great law of Mendeleef's, which states that the properties of the elements are periodic functions of their atomic weights. I firmly believe that it will be shown that the relation betwe en small quantities of elements and the masses in which they are hidden is not at variance with the same law. I have elsewhere tried to show that this may be true, by examining the effect of small quantities of impurity on the tenacity of gold.

In the case of iron, it is difficult to say what property of the metal will be most affected by the added matter. Possibly the direct connection with the periodic law will be traced by the effect of a given element in retarding or promoting the passage of ordinary iron to an allotropic state, but the future of steel will depend on the care with which we investigate the nature of the influence exerted by various elements on iron, and on the thermal treatment to which it may most suitably be subjected.

Is it not strange that so many researches should have been devoted to the relations between carbon, hydrogen, and oxygen, in organic compounds, so few to the relations of iron and carbon, and hardly any to iron in association with other elements? I think the reason for the comparative neglect of metals as subjects of research arises from the belief that methods which involve working at high temperatures are necessarily inaccurate, but the school of St. Claire Deville has shown that they are not, and there are signs among us that our traditional love for the study of metals is reviving. Of course it cannot be that chemists and physicists are afraid that "science will be degraded by being applied to any purpose of vulgar utility," for I trust that I shall at least have shown that the empire over matter, and the true advancement of science, which I suppose is the object of all research, may be as certainly secured in the field of metallurgy as in any other.

ELECTRIC WINDLASS AND CRANES AT THE PARIS EXHIBITION.

On the east side of the central transept of the machinery hall is a considerable collection of cranes, blocks, and systems of hoisting appliances, among which may be easily distinguished a large portable electric crane, for loads of 12 cwt., exhibited by the Compagnie des Entrepots et Magasins Generaux de Paris, and constructed for them by the firm of Mons. C. Guyenet, of Paris.

A little further on is noticeable a large hand power fixed crane, constructed by the same engineer, and employed in the raising of the principals of the Eiffel tower.

The maximum load lifted by this crane is three tons, and it is fitted with a special arrangement of slow-pitch screws for its elevation on the tower as the work proceeded.

Views are here shown of a variety of forms of steam and electric cranes by the same contractor, and the details of the Roux, Combaluzier, and Lepape hydraulic lifts to the first floor of the Eiffel tower, which were erected by the Guyenet firm in the east and west pillars.

In addition to this, an electric windlass and portable crane are exhibited in action in Class 63, situated in the central transept, for particulars of which, together with photographs of the apparatus, we are indebted to Mons. Guyenet.

The electric motors employed are Gramme machines, constructed by the Compagnie Electrique, current being supplied by a 5 horse power Gramme dynamo fixed in the adjoining exhibit of the company, and running off the main shafting.

The portable crane—Fig. 3—has been more particularly designed for employment in grain, wool, and sugar warehouses, etc., where rapid stacking of bales is required; a large use having been found for the apparatus, possessing, as it does, in many ways an advantage over the ordinary labor method with ladders or inclined planks. Bales, as they arrive by the hoist to the required story in a building, are run on a trolley to the portable crane, by which they are picked up, slewed, and stacked at the rate of one hundred 2 cwt. bales in twenty minutes, and when one stack is finished the crane is easily moved on further and another begun.

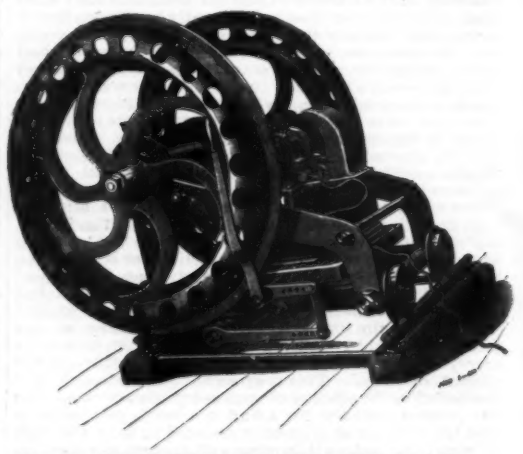


Fig. 1.—PORTABLE ELECTRIC WINDLASS.

We shall now describe the details of the mechanism of these apparatus, which appear to us to be of special interest and proved value.

The portable electric windlass exhibited, which was brought out by this firm last year, is represented in Figs. 1, 5, and 6. It is constructed to raise a load of 3 cwt. at a maximum speed of 200 ft. per minute, and therefore exerts over 2 horse power effective. The motor fitted to the windlass is, however, capable of exerting 4 horse power, the speed being from 1,200 to 1,500 revolutions. The mounting of the motor speed reducing and reversing gear is of special interest. In the first place the machine, as a whole, is mounted on a strong wrought iron trolley, which can be run along on rails, and the motor, which is a small Gramme machine, is mounted on the trolley with its armature spindle parallel to the line of rails. The motor is not a fixture, but is supported by a central shaft, G^1—Figs. 5 and 6—parallel to its own spindle, upon which its bed plate rests centrally, and about which, as an axial pivot, the whole motor can be inclined on either side of the vertical at will.

We must, however, first describe the connection between the motor shaft and winding drum, C. The drum is divided into two portions for the purpose of employing two hauling ropes wound in opposite directions, but the whole drum is keyed to one central shaft, parallel to the motor shaft, and supported by wrought iron brackets or girders, bolted to the trolley, as shown. Keyed to the drum shaft are two fly wheels, E E^1, about 4 ft. diameter, one at each end of the shaft, which are provided with internal grooves about 4 in. wide, presenting, therefore, two friction surfaces, F and F^1, to each fly wheel.

These grooves will be noticed in the illustration on the internal faces of the fly wheels, that is, facing inward.

Referring again to the motor, it will be observed that the armature spindle is prolonged some little distance at each end beyond the plummer blocks, and to each end is keyed a small friction pulley about 3½ in. diameter. These friction pulleys, H and H^1, fit inside the internal friction grooves or crowns of the two fly

wheels, between the two sides of which they have a slight amount of play.

It will, therefore, be seen that by rocking the motor about the central axis on which its bed plate rests, the small friction pulleys are pressed against one side or other of the fly wheel friction grooves, and the winding drum rotated in one direction or the other at will, while the motor runs continuously in one direction. The motor is rocked on either side of the vertical by means of the lever, S, which, when moved to the right or left, turns round the shaft, P, running freely through the motor bed plate.

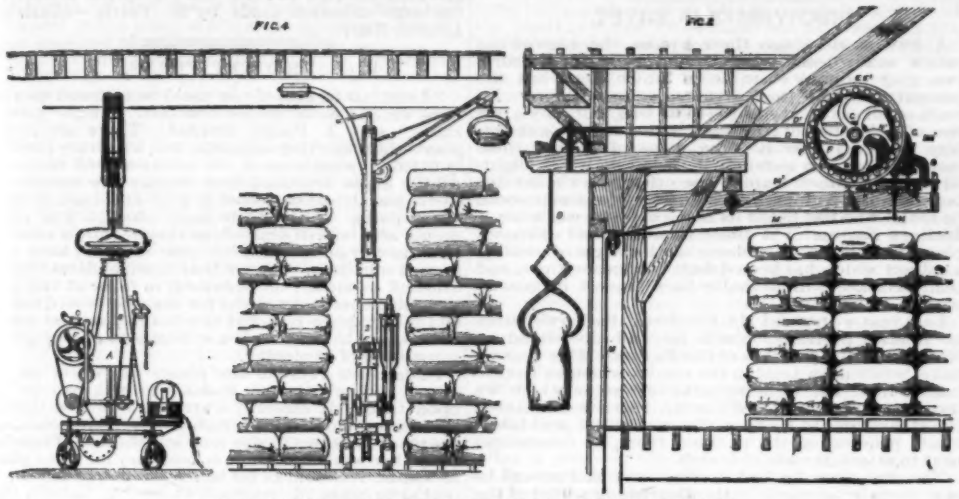
At one end of this shaft—Fig. 6—the movement is transmitted to the spindle, J, by a link, T, and this spindle is connected on one side with the motor bed plate by the link, R.

It follows, therefore, that whichever side the lever, S, is moved, the motor is canted over the same way, and, therefore, by this lever the motor can be thrown into gear with the drum, so as to rotate the latter in either direction.

In these apparatus it is an essential feature that a brake should be automatically applied when the machine is not actually performing work. This is accomplished by the brake block, K—Fig. 5—fixed to one end of a horizontal lever pivoted at J, and carrying at its other end a counterpoise, L. The fulcrum of this lever is a sleeve on the spindle, J, and therefore does not turn with it.

As seen by the diagram, the brake is applied when the lever, S, is released, but on moving this lever to the right or left the shaft, P, is turned, and with it the lever, W.

According to the direction in which S is turned, one or other of the rollers at each end of the lever, W, is raised, the counterweight being, therefore, lifted in either case, and so the brake released from the wheel. It will also be seen that the counterweight, L, exerts a continual downward pressure on the lever, W, and therefore causes it to return always to the horizontal position on the release of the controlling lever, S. This insures the automatic application of the brake, and the equilibrium of the motor when the machine is not in action.



PORTABLE ELECTRIC CRANES AND WINDLASS.

For employment in unloading and raising goods to the upper stories of warehouses M. Guyenet erects the windlass, as shown in Fig. 2. In this case it is more convenient to control the action from below, and, therefore, the hand lever is replaced by two levers, N N¹, diametrically opposite on the shaft, P, connected respectively to two cords, M M¹, which pass over pulleys to the ground level. From below, therefore, or from any convenient height, the winch can be set in action in either direction. The automatic brake acts, as before, immediately the cords are released. Two hauling lines are employed, so that one load can be attached below while the other is being detached above.

These lines, D D¹, pass over pulleys, and are wound respectively on each half of the drum in opposite directions.

These windlasses are extensively employed by the Compagnie des Entrepots et Magasins de Paris, in grain and sugar warehouses, and for the unloading of barges at wharves.

The portable electric crane—Fig. 3—designed specially for stacking goods, consists of a framework, A, built of iron plate and angle iron to which the electric motor is bolted, and upon which is pivoted a hollow vertical post, B, of channel iron. At the top are the two wings with their tie rods, one supporting the load and the other the counterweight. The whole is mounted on four wheels, whose bearings are attached by a fork to a vertical axis, so that the crane can be turned round sharp at right angles, or on itself when required. The crane is built specially of narrow dimensions, so that it can readily pass through the passages left between the stacked bales—see Fig. 4. In doing so the wings at the top are slewed round in the direction of the passage, and can be lowered if necessary to pass under the joists of the building. The tie rods at the top are fixed respectively to opposite ends of a small lever, which can be turned by means of a long vertical lever, thus effecting the lowering of the wings. This lever is ordinarily kept fixed to the central post by a pin.

FIG. 3.—PORTABLE ELECTRIC CRANE.

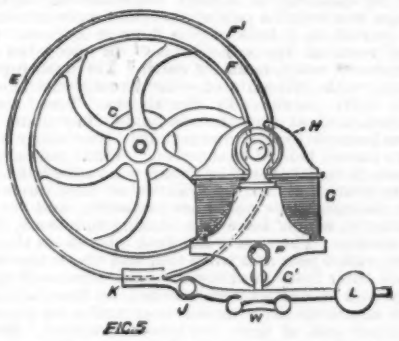


FIG. 5

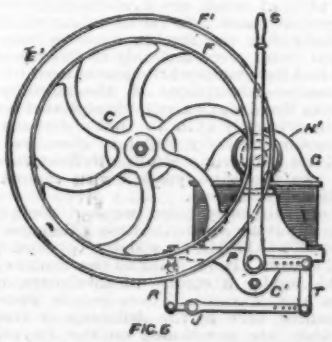


FIG. 6

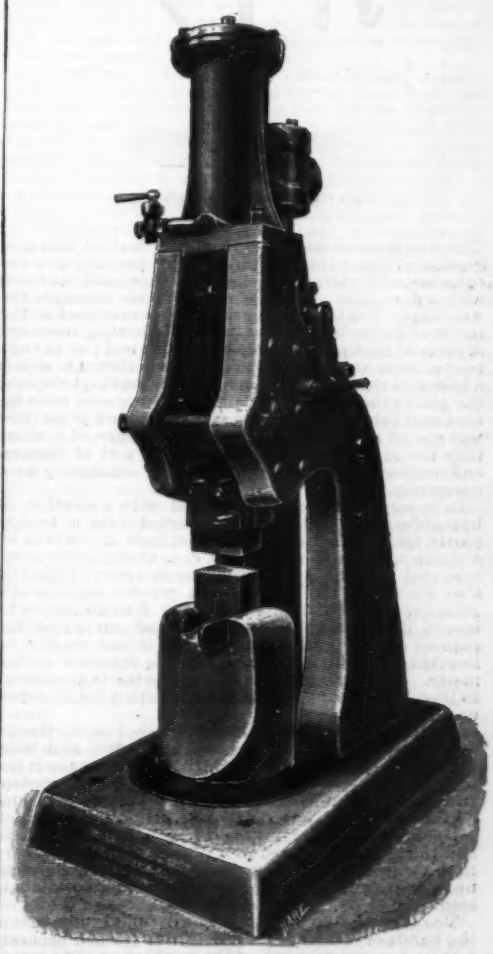
A short length of countershaft is fitted to the frame, to which is keyed a large pulley, connected direct by belting to the motor pulley and a small flanged pulley, which runs by belting a large flanged pulley, F, on the winding drum shaft. By this means the speed of the motor is reduced about fifteen times. The belt connecting the two flanged pulleys is normally slack, and only tightened when it is required to throw the motor into gear and lift a load. This is effected by the simple movement of pulling the cord, H, which will be seen in the figure to pass over a fixed pulley at the top, under a pulley attached to a lever arm below, and up to an anchorage on the frame. The lower part of this lever is a bell crank, on one arm of which is the counterweight and cord pulley, and on the other a small flanged pulley standing opposite the slack belt. If now the controlling cord is pulled, the flanged pulley on the lever is forced against the slack belt and tightens it into gear. Before this is sufficiently tightened, however, to run the winding drum, the brake is, by the same action of the lever, removed. The brake blocks, G, are carried by a lever pivoted on a spindle fixed to the frame immediately below the blocks, the longer arm being connected by a link to the center of the flanged pulley on the bell crank lever. The same movement therefore that tightens the belt and puts the motor into gear first lifts the brake blocks off the winding drum pulley. Slewing is easily done by a cord attached to the hook holding the load, as the whole of the upper part and vertical supporting post turns on a central pivot. The hauling rope passes from the barrel round a pulley attached to the frame below the post, up through the center of the post over a pulley at the top, and over a third pulley at the end of the crane wing. The work of stacking is therefore reduced to a very simple operation; the cord, H, is pulled downward until the load is raised, and is then released to apply the brake. After slewing round, the load is lowered into its position by pulling the same cord, this time sufficiently to remove the brake, but not to tighten the belt. Again, to obtain the full advantage of the crane, it is necessary that loads should be lifted as close as possible to the pulley on the wing, and therefore that a minimum of space should be occupied by the lifting claws. This has been accomplished by a pair of claws specially designed, which take up no more room than the sack, and which grip automatically as soon as the lifting force is applied.

The crane exhibited weighs in all one ton, and raises a load of 2 cwt. at 120 ft. per minute, with a 2 horse power motor running at 1,200 revolutions.

There are several installations of these appliances in Paris, also at Roubaix, Havre, Tergnier, and Rouen, where they are in use in various warehouses for unloading, hoisting, and stacking goods.—*The Engineer.*

IMPROVED STEAM HAMMER AT THE PARIS EXHIBITION.

WE illustrate from *Engineering* a novel type of steam hammer exhibited at Paris by Messrs. B. & S. Massey, of Openshaw, Manchester. The chief interest lies in the frames and the base plate, which are each pressed out of a single plate of steel without weld or joint. Further, the cylinder cover, the piston rod, and the hammer head are each of steel. The falling mass is nominally of one-half cwt., but actually something more, and it has a stroke of 12 in. The total weight is about one ton. The firm are making larger hammers with the same class of framing.



STEAM HAMMER AT THE PARIS EXHIBITION.

A SIMPLE UREAMETER.*

By Prof. L. E. Sayre.

It is, perhaps, conceded by the pharmacist generally that that part of chemical analysis involved in the examination of urine is a branch of chemistry which comes very properly within the lines of professional work of the pharmacist. It may be urged that the physician is quite competent to make all the examinations necessary of this kind; the majority of young men now graduating at our medical colleges being well equipped for accurate urinary analysis. While this is true, physicians in active practice who are convenient to a pharmacist will not always take the time nor give the patience to making repeated, careful analyses such as are demanded in some classes of disease. I was impressed with this fact some time ago, while visiting in one of our large cities. A physician wanted a quantitative determination of samples of urine; he was able to do the work himself, but was one of the class I have described. It fell to my lot to accommodate him, as the pharmacist (my friend) to whom he applied did not feel himself competent to perform the work. This incident forcibly brought to my mind the importance of the pharmacist's being fully equipped for chemical work of this sort. He has the time, and the busy practitioner has not, and such chemical service as this, rendered to the physician or the patient, is sometimes of pecuniary benefit to the pharmacist.

In the college laboratory the pharmaceutical student of to-day receives a more or less thorough course of instruction in this branch of chemistry, which shows a recognition of this matter on the part of the pharmaceutical institutions of instruction.

In the instruction of the student in urinary analysis, it is especially desirable that he be educated to use the simplest forms of apparatus and to make these simple forms to have as wide a range of application as possible. It is the attempt to carry out this principle last winter in this class of work that suggests the present article. It became necessary to extemporize some home-made instrument for the use of each individual member of the class, to be used as a ureameter. With but a few suggestions on my part, the students made the following: A piece of soft glass tubing 10 inches long and ⅜ to ½ inch in diameter, was provided. Over the Bunsen burner one end was carefully rounded and closed, making a sort of long and narrow test tube.

SAYRE'S UREAMETER.

This was covered with a thin film of melted wax and graduated into cubic centimeters by pouring into the tube metallic mercury, 1 c. c. at a time, and marking with a fine point each c. c. on the glass through the wax film. The tube thus graduated was etched in the fumes of hydrofluoric acid in the following manner: A piece of lead pipe was closed at one end; at the opposite, open end, a cork was provided, through which a hole was cut, just large enough to admit and suspend the glass tube. Fluorspar and sulphuric acid were introduced into the pipe, and the suspended glass tube was placed in position. After an exposure of a short time the etching was complete, and a sort of Bunsen eudiometer was made, which served admirably as a ureameter.†

In using the tube, it is first filled with a solution of hypochlorite of sodium and inverted into a beaker partly filled with the same liquid, held in position by a clamp as represented. One c. c. of the urine is introduced into the tube by means of a curved pipette, also shown in the figure. The pipette consists of a glass tube $\frac{1}{4}$ inch in diameter and 8 to 10 inches in length, drawn out to a fine point and curved at the pointed end, at such an angle that it can readily be inserted up a little distance into the inverted eudiometer. The straight arm of the pipette is graduated so that between two marks, made with a file, it measures 1 c. c.

This simple instrument has so pleased me in the accurate results which it gave, and in the drill and independence it gave the students, that I have made it the basis of a paper to be read among our San Francisco friends. The students realized that they could be independent of the more elaborate instruments which are being figured from time to time in the journals, and the results obtained were always more satisfactory than those obtained from the use of the Prof. Doremus ureameter, which appears to be the more commonly employed.

The objection to the latter I have found to be that in the hands of the students it does not furnish accurate results, because so much of the gas is allowed to escape at the open end. I have had the students compare their own with the Doremus instrument, using a solution of urea of known strength for the purpose. As a result they report that the eudiometer always shows more exactly the quantity of urea, gives more nearly the theoretical quantity of gas, than the ureameter of Dr. Doremus. I may add that this has been my own experience as well.

I have no doubt that this simple and inexpensive piece of apparatus has suggested itself to others, but there may be some of the craft who may not have had occasion to think of it, and may appreciate this reference to it.—*Amer. Druggist.*

* Paper read at the meeting of the Am. Pharm. Assoc. at San Francisco.

† It will suggest itself to any one, perhaps, that a long, narrow test tube, graduated on paper, will answer for extemporaneous ureameter. L. E. S.

DISCOVERIES IN EGYPT.

A few months ago there lay, on the edge of the yellow sandy desert some sixty miles south of Cairo, two gray patches of ruins, of which none but the peasantry around them even knew the existence. No walls or tokens of work were to be seen, but only a low rise of a few feet of Nile mud, with some chips of pottery scattered over it. The name of one of these mounds was taken merely from the ravens which alighted on it—Medinet Gurob; the other, a few miles distant, scarcely had even a name—only one man could be found who had heard its name when he was a boy—Medinet Kahun. Yet these unnoticed and unknown places have given us evidence on the origin of writing, a subject which has been debated for generations, and their evidence will probably be discussed by generations to come.

Last year we noticed Mr. Flinders Petrie's exhibition of Roman portraits, which he had discovered at Hawara, in the province of the Fayum. This year we have before us in London the results which he has obtained from the hitherto unknown ruins which we have just mentioned. While Mr. Petrie was finishing the excavations at Hawara the past winter, and laboriously penetrating the pyramid there, he determined next to attack the site of Gurob.

The first time he had walked over that mound he saw that it belonged to the flourishing period of the great Rameses; for to the practiced eye chips of pottery are as intelligible as printed words and dates. While working there he walked over the blank gray swell of Kahun—this was clearly of a still earlier date, for none of the pottery was of any style yet known. On digging here this proved to be the town built for the workmen who labored at the pyramid and temple of Usertesen II., one of the great kings of that remote age—the XIIth Dynasty, about 2,600 B.C.

The houses, the agriculture, the tools, the ornaments, the literature, and even the amusements of more than four thousand years ago are brought vividly before us by these discoveries. The dancing profession is of immemorial age in the East, and the acrobats and performers of the early times are pictured on the walls of the tombs; here we have a wooden statuette of a dancer or mummer, dressed in a mask, and a tail, and —nothing more.

The strange animal headdress which she wears is evidently much the same as that in which Bes, the god of dancing, is always represented. With this image was found a pair of ivory clappers or castanets, all buried in a hole in the floor of a room. In the next room of the same house was found the actual mummer's mask, made of canvas and plaster, painted black, with crescents of color around the eye-holes, and with patches on the cheeks. Torn, patched, broken, and at last thrown aside, how many antics have been performed under that! How many miseries have passed behind that screen! What jests and what shame it had covered! Perhaps no relic has brought us so touchingly to the frailties of past humanity as the dancing girl's mask, her castanets, and her little statuette, which have lain during thousands of years in silence. The merry children played in the streets then with tipcat and whip top, and threw the ball and made their little mud toys; quaint figures of men and pigs and crocodiles were pinched up from bits of clay, and a curious little model boat and a hippopotamus chipped out of flint are here illustrated. We know how the Egyptians obtained fire, a point never yet discovered until the fire stick came to light. On this an upright stick would be rotated, so as to ignite the powdered wood by friction, as in India at the present time. Delicate and graceful wood carving is shown in the wooden spoon shaped in the form of a shell supported by a serpent.

A sling, far older than that of David, shows us how carefully such things were woven and provided with a loop to hold on the finger. Tools were strangely like modern forms; the plummet, the brick mould, the plasterer's float, might any of them belong to an English workman as far as their form goes. It is only where metal has come into commoner use and driven out the wooden hoe and the flint saw in the sickle that any essential change is to be seen. The music of the time was much the same as now, as we see by the boy playing on double pipes like a modern Egyptian.

The greatest discovery, however, in this ancient town is that of alphabetic writing, quite distinct from any Egyptian inscriptions yet known—neither hieroglyphic, hieratic, nor demotic. Dozens of signs are found upon pottery, as the marks of the owners, and on one piece of wood are five letters, evidently forming a word or name. So far as yet examined, it seems most likely that the foreign captives from the Mediterranean (who were certainly in this town, by other tokens) had here adopted the marks used by the Egyptian masons—corruptions of the heiroglyphs; and then from these signs a syllabic alphabet was formed, which is evidently akin to that of Cyprus, and, perhaps, some other early writing. Here we are on the track of the very origin of all our Western writing, at a date two thousand years before almost all of the inscriptions yet known.

Leaving this early town, we will come down some thirteen hundred years to the time of Rameses the Great, or about 1400 to 1200 B. C., which is revealed to us in the town of Gurob. Here, amid all the works of that age, we find again a colony of foreigners, comprising Hittites and Turseni. These people were probably accompanied here by the Achæans or Greeks, with whom they are mentioned on the Egyptian monuments of that age. The same Cypriote characters are again found here on the pottery; and, moreover, a great variety of the earliest Greek pottery, exactly like that found in the oldest remains of Mycenæ by Dr. Schliemann, and that from beneath the lava beds of Thera. The false-necked vases and the figures of pottery might be supposed to have come from Greece itself, and not from a colony in a remote part of Egypt. The historical value of such a well-dated discovery is immense, as we now have for the first time a solid basis for our chronology of the prehistory of Greek civilization. The beautiful head carved in wood comes from a coffin of about 1300 B. C.; and the elegant but less artistic carving of the head belongs to a few centuries later.

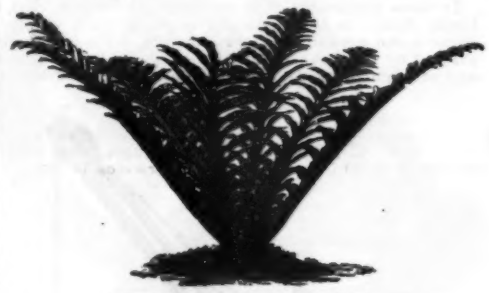
We have barely indicated the most curious objects, without touching on the beautiful necklaces, amulets, and embroideries, and the other historical interests of the large collection made by Mr. Petrie.—*Illustrated London News.*

BRACKET FERNS.

"I should be glad if you could recommend me a few ferns which I could use for brackets. I have platyceriums," says J. Foden, Halifax. There are several plants well deserving attention, and which are peculiarly fitted for situations of the above-named character. All the kinds described here require the warmth of a stove, and should be potted in peat and loam in about equal parts, with a little sand added. The plants should also be well drained, as they require a considerable amount of water all the year round to keep them in good condition. I know that in some places they are dried off in winter, the argument in favor of this practice being that it is natural for them to be so dried up, and they require rest, but this is a foolish and absurd notion, and to teach such a system is to encourage the worst form of gardening.

Under such a system the plants can never be any larger, and only the one season's growth can be had upon them. If carefully nurtured, however, through the winter months, the freshness is maintained, and the plant increases in size and stateliness. Therefore, I say that while less water is necessary for these plants in winter, it should never be curtailed to such an extent as to cause the specimens to suffer; indeed, there is not a single fern in cultivation, be it evergreen or deciduous, that is benefited by an entire withholding of the water supply. The following few kinds should form splendid ornaments as bracket ferns in a well-arranged fernery, all that is necessary being to drain the pockets or brackets well and to allow sufficient head room:

Aglaomorpha meyeniana.—This plant has acquired the name of bear's-paw fern from its very stout rhizome being covered with thick woolly scales, which are of a bright red; the fronds attain a length of some 3 feet or more, and are thick and leathery in texture; they grow erect, are divided in the lower part nearly to the stem into somewhat broad, oblong entire pinnæ, which



DRYNARIA MORBILLOSA.

are closely set and long and narrow. It is a native of the island of Luzon.

Drynaria coronans.—This is a very handsome species, with large, broad fronds, which are erect and arranged in a circle, hence its name. It has a stout and woolly rhizome; the fronds each attain a height of 4 feet and about 2 feet in breadth, tapering slightly upward, and divided into broad pinnæ; these are not contracted like those of the previously named plant, otherwise it is similar. It is a native of Malacca.

D. morbillosa (see illustration), sometimes called D. heraclea, is a bold, large-growing plant, which in large examples attains a height of 6 feet by 2 feet in breadth. It is rigid in texture, and the base is wide and cordate. It is a beautiful object in any position in a fernery, and comes from various islands in the Malay Archipelago.

D. quercifolia is a distinct and pretty plant with dimorphous fronds, the barren one being sessile and lobed toward the top, in shape something like a large oak leaf; the fertile frond is some 2 feet long and pinnatifid; the barren frond usually dies annually, but remains on the plant. It is a very suitable plant for brackets, and forms an elegant ornament. It is a native of Moulmein and various other parts of India.

Hymenodium crinitum is a bold, handsome species, and it has obtained the name of the elephant's ear fern, and its large entire dark green fronds give a very good foundation for the name. These are simple and entire, some 18 inches long and about 9 inches broad, deep green covered with very long black hairs. The stem is from 6 to 9 inches long and covered with black hairs. This plant is found in Jamaica and several of the West Indian islands, and it requires an abundant supply of heat and moisture. If used for the purpose here indicated, it should have a moist shady situation selected for it, so that the edges of its fronds may be preserved, otherwise these become brown and shabby. When grown into a good specimen it is a distinct and magnificent fern.

The above are a few kinds suitable for brackets, and if used alternately with platyceriums (the stag's horn fern), will render a fernery very attractive.—*W. H. Gower, in The Garden.*

SOME PHYSIOLOGICAL TRAITS OF THE SOLID-STEMMED GRASSES, AND ESPECIALLY OF INDIAN CORN (MAIZE).*

By F. L. Stewart, Murrysville, Pa.

The laws of nutrition and growth are at the present time understood to cover a few general principles, which, as far as we are capable of comprehending them, embrace in their range of action all manifestations of

* Paper read before the section of biology (F) of the American Association for the Advancement of Science at Toronto, Canada, Aug. 29, 1889.

life, both vegetable and animal. But in attempting to trace out the life history of any organism we must assume for the plant and the animal respectively two different starting points. The plant almost at the outset of its career goes to building up its tissues from inorganic materials within its reach. The animal can appropriate to its use only the elaborated food materials which the plant has first provided.

As a biological study, the phenomena of plant life are therefore the most interesting and important, for it is the plant that lies at the base of the scale, and the closest to the heart of the great mystery which involves man and all animate nature alike.

The plant has therefore a double office to perform, and inasmuch as the principle therein involved has much to do with the subject matter of my sketch, I prefer to define it in the language of one of our best authorities in vegetable physiology.

"Plant nutrition includes two very distinct stages. Certain parts of plants build up, as every one knows, from external inorganic materials, substances which are available for the construction of new tissues. It might be supposed that these are used up as fast as they are formed, but it is not so. The life of the plant is not a continuous balance of income and expenditure. On the contrary, besides the general maintenance of the structure, the plant has to provide from time to time for enormous resources to meet such exhausting demands as the renewal of foliage, the production of flowers, and the subsequent maturing of fruit. In such cases the plant draws on an accumulated store of solid food which has rapidly to be converted into the soluble form, in which alone it is capable of passing through the tissues to the seat of consumption." (Address of W. T. Thiselton Dyer, president of the biological section of the British Association, annual meeting, 1888.)

It must be said, however, that the common demands made upon the plant, enormous and exacting as they are, do not reach the limit of the resources for which it has sometimes to provide. In some of the grasses especially the accumulation of reserve products or true food materials in persistent parts of the structure occur under certain circumstances when the future wants of neither foliage, flowers, nor fruit are to be provided for, and when distribution of the stored products to those parts, to any considerable extent, is impossible.

Acting upon a belief that the plant sometimes uses processes and exercises functions not clearly referable to known physiological principles, I was led a few years ago, in the course of an investigation of the chemical constitution of some of the solid-stemmed grasses, to attempt to reconcile certain physiological characteristics of maize with those exhibited by some other members of the group with which it is commonly classed, and to which it seems naturally to be the most closely allied.

Special interest centered in the fact that these peculiarities were rather functional than structural.

In one respect particularly this species was in marked contrast with not only our other cereal grasses, which are hollow-stemmed, but it was also clearly distinguishable in some of its functions from others of its own narrow group, which structurally it very closely resembles.

As a result of the intense activity of the constructive forces in this plant, a great accumulation of reserve materials is constantly maintained, which are stored up in the bulky, parenchymous culm. For any present purpose or indeed for any plain future purpose of nutrition these stored materials seem always to be greatly in excess. The income of the plant through all the ordinary period of its growth vastly exceeds the expenditure.

Reasoning from analogies furnished by other well known allied plants, such for example as sorghum, it might be supposed that the carbohydrates which constitute almost the entire solids in the juice would remain stored up in the cells of the plant *after the seed has ripened.*

But the full ripening of the seed of maize is attended by the following phenomena.

At a period coincident with the glazing or hard ripening of the grain, there is a sudden and utter impoverishment of the cell sap, as revealed by chemical test and microscopic examination; and if samples be cut and weighed shortly before and after this change has occurred, it will be discovered that in the latter case there is a loss of weight almost exactly equal to that of the dissolved carbohydrates, the sugar having suddenly disappeared.

This disappearance is rapid and complete, and it is not due to fermentation—meaning thereby the destructive process the products of which are carbon dioxide and alcohol—nor is it attended by any of the ordinary marks of putrefactive change.

If a maturing stalk of maize be cut down before this period, the evaporation of the water of the juice and the destruction of the sugar is gradual, but if it be cut when the final stage of development of the plant has been reached, the stage of "hard ripeness" of the seed, the water evaporates with amazing rapidity, which I think is partly accounted for in the fact that the cell sap holds no longer the substances in solution which would hinder its rapid transmission through the cell tissues but chiefly from the fact that the protoplasm in great part has also disappeared.

If the protoplasmic lining remained, or remained adherent to the cell walls in the dead plant, it would either greatly retard or hinder altogether the transmission of water through the cell tissues. But it is a property of dead protoplasm to contract and separate in rolls from the walls of the cell, and wherever it is found to remain, it is in that condition. The dead barrier lining being thus removed, there exists no physical obstacle to rapid evaporation. Moreover, the destructive process is attended by shrinkage and rupture of the cellular tissue itself. This is especially notable in the parenchyma bounding the lacunæ or intercellular spaces in the vascular bundles, which by contraction of the tissues become enlarged to many times their usual size, and being filled at this time like the other vessels with air only, evaporation is thus greatly facilitated.

In passing, I may remark that this disappearance of the soluble carbohydrates, either total or in part, has direct relation to the particular stage of ripening at which it occurs, and now accounts for a loss of substance, not water, incurred in the curing of corn fodder.

I have found that corn fodder cut after a certain stage of ripeness of the grain (presently to be indicated) has been overpassed is subject to immense loss of nutritive substance, all of which may be saved if the proper conditions be complied with. This circumstance is of great practical importance.

As already said, at the period of time when the glazing or hardening of the grain occurs, a culminating point in the development of the plant appears to be reached. A rapid change takes place in the chemical constitution of the grain substance, and the culm, from being a reservoir of food materials for the use of the plant in which those materials have reached the highest point of elaboration, is suddenly stripped of everything that gave it interest and value. Those who have watched up to this point the gradual transformation as it went on in the living plant, noting the change from day to day of the simpler into the more complex products, largely into that highest product of the constructive metabolism—cane sugar—might well be pardoned for thinking that they see in all this the promise of results in practical sugar manufacture of transcendent value, and in which none of this accumulated saccharine richness would be wasted. But invariably in the natural order of things this hope is blasted, a break-down of the constructive forces suddenly occurs, and as unexpectedly as it is sudden. Within a period generally of but a few hours the culm of the plant is left but the barren framework of the former structure, and if cut down, is soon recognizable only as the typical dead cornstalk, a worthless mass of empty circulatory vessels, exhausted parenchyma, and dead protoplasm.

This is the result of the natural death of the plant, and if this were all that remains to be said I would not have taken up the time of a scientific body in discussing it.

But a study of the circumstances under which it occurs shows unexpectedly how this catastrophe may be averted, and reveals a train of phenomena which prove that the plant, in all parts of its structure considered apart from the portion carrying the seed, is capable of existing under greatly changed conditions and of exercising enlarged or entirely new functions.

I will state what these are as briefly as possible. If we go back in our study of this plant to an earlier stage in its development, we see that the seed in the so-called green or immature condition has properties and is adapted to uses widely different from those of the hard-ripened corn. What these are will presently be more fully shown, and it may be said that their true value is just beginning to be acknowledged.

It is well known that the further development of the grain may be arrested by its removal from the stalk, and its condition fixed—with all its properties retained—by desiccation, in a very simple way.

Maize, then, is capable of yielding its grain product in one of two widely different conditions, as widely different, in fact, as those of two distinct species of grain. Ripeness may be affirmed of either, if by that term is meant first the possession by the grain in both conditions of high germinative power, for both will grow, and second, a state of perfection which fits it for use as food. We can have either kind of the grain at will, and our ability to secure either gives us a variety in the choice of food, from this single source, not approached by the products of any other plant. We have, in fact, two series of food products, widely different, derived simply from the grain in two different and successive stages of development.

If our choice be the grain in the earlier stage, it is hardly possible for me to repress astonishment that a still more remarkable fact than any yet adverted to—of the highest physiological as well as economic interest—should have utterly eluded observation up to this time. I refer to what happens to the corn stem after the immature ear has been removed.

A false analogy would lead us to suppose that the purpose of the plant's existence is wholly met in the production of its seed, and, that done, in a way to satisfy the conditions of successful reproduction, vital functions would cease. Yet nothing could be farther from the truth.

What does follow is this:

Contingent upon the excision or removal of the ear in its first stage of development (the so-called unripe condition), the arrest of the vital functions which invariably accompanies the second stage of ripening of the grain *does not occur. The plant lives on,* and in a condition of existence which carries all the marks of active development and growth. Without a break, the constructive forces go on with their work of converting the simpler into the more complex reserve materials. The culm is their storehouse, and under the new conditions that part of the plant *passes through a second period of development.* Its function then is to accumulate sugar. To this the insoluble and less complex soluble products give place. The starch formed in the young stems during the first stage almost entirely disappears. There is a sensible increase in the nitrogenous substances keeping pace with the soluble carbohydrates.

A peculiar acid, the maizine, the properties of which are worthy of fuller investigation, is found in the juice at all periods. The stem had attained almost its full size by the time that the ear was fully developed. During a period of from forty to seventy-five days, which in different varieties of maize I have found to measure the length of this period, the stem hardens externally in conformity with its endogenous structure and mode of growth. The tissues of the epidermis assume generally a deep red or purple color, and occasionally there is a tendency to send forth new leaves.

But the vital energies are directed specially to the storing up of highly organized food materials in the cells. It is a period of juice-ripening, so to speak, borrowing a term from an analogous process which is carried on in the maturing joints of the sugar cane—a plant to which maize bears naturally a close relationship. In attempting to describe this anomalous condition of Indian corn, I hope I may be pardoned for seeing in this analogies which the plant does not sustain in what we call its natural condition.

1. In both plants the solid stalk or culm has become simply a reservoir of reserve materials, available for plant food, and, in the case of the sugar cane, made use of when active growth by the joints begins.

2. In both, the development of the organized products is progressive, from the more simple to the more complex, of the series—which take the soluble form and are available for transmission to build up other parts of the structure.

3. By reason of the constant accumulation of these soluble materials chiefly, the weight of the plant and the density of the juice increases.

4. In both, the general physical properties of the stem are the same, the separate joints in the one and the whole culm in the other attaining their full size before the highest elaboration of their juices takes place.

5. It is a well attested fact that no variety of sugar cane is known to perfect its seed or, to use the language of Wray, to produce anything like seed either in India, China, the straits of Malacca, Egypt, or the South Sea islands. By a curious analogy, maize in this secondary stage of development is incapable of transmitting its new qualities by the seed, for the sufficient reason that it likewise is then incapable of producing seed, having apparently exhausted its capacity in that direction.

There are other points of resemblance which it would be interesting to note, but the point of comparison to which no doubt most interest will be attached relates to a question of great practical interest, the discussion of which, however, is no part of my present purpose.

I refer to the high saccharine character of the juice of the plant when it is in the condition already described, and desire to call attention simply to the summary of the results now reached as derived from investigations carefully conducted during the past five years continuously upon every variety of maize ordinarily grown within the United States.

It is shown that from the time the sugar first shows its presence in the cell sap during the earlier growth of the plant, and until the grain begins to harden, it steadily accumulates and then suddenly disappears. It contains, then, 6 to 8 per cent. of sucrose and 1 to 1½ per cent. of grape sugar. Another of the solid-stemmed grasses—sorghum—up a corresponding period manifests the same characteristics, but there the resemblance ends. Sorghum retains its sugar when dead ripe, maize parts with hers then utterly. Can our science tell us why?

Arrest the development of the ear of maize at the critical time, and the threatened catastrophe, the destruction of the sugar, is averted, and not only so, but its accumulation goes on. The average of 7 per cent. of sucrose in the juice in August, in the latitude of Pennsylvania, mounts up then to 12 in September and 14 in October, and still higher if it escape severe cold during early November. A stalk of field corn of the "Golden Beauty" variety, taken in October with its juice well ripened, the grain having been separated from the stem in August, will average three pounds weight when stripped. Single stems have been obtained of nearly double that weight when in the same condition. It is worthy of remark that in these circumstances the plant exhibits a hardihood to resist cold to which in its earlier period of growth it was entirely a stranger.

In short, the conditions are the arrested development of the ear (its removal without much laceration of the supporting stalk) and the continued connection of the plant with the soil, with ordinary access of sunlight and air.

Time will not permit me to refer to the numerous valuable qualities and uses of the grain when separated from the stalk and properly cured at the earliest stage of its development.

It is destined to be the basis of a much greater variety of palatable and nutritious food preparations than the grain when dead ripe, and in the fact that its chemical constitution approaches wheat more closely than that of any other grain, and that it is free from the objectionable qualities which have hindered hard corn from coming into general use, it will have peculiar value.

Aside from all question of use, these peculiarities of Indian corn have rare physiological interest. Applying here the well-known principle that in the processes of nutrition there is extraordinary accumulation to meet extraordinary demands, the query is raised, What extraordinary demand is there in the economy of the plant for this remarkable accumulation of reserve products at this period? But it is well to remember that this added saccharine period is not normal to the plant as left to itself. It is the direct result of intelligent interference with a vital function—human selection, if you please—and its end is adaptation to human use.

Under the proper conditions it is a constant result, and it is a fixed attribute of the species in all its varieties.

Investigation shows that in all plants there are certain dormant tendencies to change. Of these, at first, we may know nothing, but they require only opportunity for their manifestation. Our business is to endeavor to discover them, if possible; for upon man's present intelligent comprehension of some of these and his ability to make use of them depends his mastery over nature.

Our other domestic plants, almost without exception, have had given to them by naturalists searching and appreciative study, somewhat according to their merits, but no monograph of maize has ever been written. Exact science has done much less to determine the range of its characters and to fix the value of those that are known.

The voyage of Columbus nearly four hundred years ago introduced it to the world. Does it not merit by this time more study than it has hitherto received at our hands?

HYSTERESIS.

THE term "hysteresis," according to Prof. Ewing, is used to express a tendency to persistence in an original state. It being known that the thermo-electric properties of metals were affected by stress changes, it was natural to search for other properties which were affected in the same way. Hooke's law for stretching was not rigorously exact, or there would be no such effect as he was about to describe. In his experiments he had used long wires of various cross section and material, and had suspended them, one at a time, from a rigid support, and hung weights on the lower end. A block was clamped on to a point on the wire near its lower end, and a similar block was suspended opposite to it by two wires of the same material as the long wire under test, so as to eliminate the effects of temperature variation as much as possible.

A cross piece was placed over the block and support, and this carried a mirror, upon which a beam of light from a lamp fell and was reflected on to a scale. Any elongation of the wire would obviously result in a tilting of the mirror and a consequent movement of the spot of reflected light. The wires were each 27 ft. long, and it was possible to detect an extension of one ten-millionth of this length. A weight of 14 lb. was retained on the wire throughout the experiments, and varied portions of other weights which could be easily imposed or removed. The object of the investigation was to test the degree of completeness with which the wire extended and retracted, when loads were successively applied and removed, and especially to see whether any one intermediate value of the load was associated with the same extension during the loading and during unloading. The results showed an important difference between the extensions in the two cases, the differences in some cases amounting to as much as one per cent. of the whole extension. The difference was of such a kind as to imply lagging in the extension of the wire, or hysteresis. The phenomena were observed in wires of iron, hard steel, mild steel, brass, and copper, the effect being greatest in hard steel and least in iron and mild steel. It did not seem to disappear with lapse of time, and it did not disappear when the wire was subjected to vibration. The results were probably connected with the fact, well known to engineers, that materials submitted to repeated applications of load deteriorated after a time.

BROMOFORM IN WHOOPING COUGH.

DR. STEPP, of Nurnburg, publishes in the *Deutsche Medicinische Wochenschrift* a large number of cases of whooping cough, in which he claims to have obtained most satisfactory results from the internal administration of bromoform. The drug has, according to the author, no ill effect of any kind, and his numerous observations have proved that bromoform, as applied by him, is non-poisonous, and that the pulse and temperature remain unaffected by it. The action of bromoform is entirely different from that of bromide of potassium, as has been observed in epilepsy, the former being rather an excitant than a sedative. Children are ordered from five to twenty drops during the twenty-four hours in very frequent doses. The solubility of bromoform in water being very slight, the mixture requires the addition of alcohol. The author has administered bromoform in about sixty-five cases of whooping cough, the children mostly ranging in age from six months to seven years. The longest time required for a complete cure was four weeks. Symptoms of pulmonary catarrh in all these cases were entirely absent, or else they were very slight and soon disappeared. No complications existed in any of the cases observed by the author, but Dr. Goldschmidt has treated several serious cases of whooping cough complicated with pneumonia, completely curing them in a fortnight by the daily administration of bromoform. Dr. Stepp concludes from his observations that under bromoform treatment bronchial catarrh and lobular pneumonia do not generally occur, and that where they exist at the commencement of the treatment resolution takes place with facility and at an earlier period than under other methods of treatment. His observations showed also that the dose of bromoform must be in direct proportion to the severity of the affection and the age of the patient. The system does not seem to become accustomed to the drug, which has, moreover, considerable prophylactic power, so that the other children of a family in which whooping cough in an advanced stage already exists can be shielded from the disease by being given bromoform. Dr. Stepp believes that bromoform is either excreted unaltered by the lungs or is separated into its elements, and that the free bromine is excreted by the lungs. In this way an effect on the bacilli of whooping cough could be easily supposed to result.—*Lancet.*

ARSENIC IN WALL PAPER.

D. H. GALLOWAY critically examined a large number of wall papers from many different sources, with the object of ascertaining if and in what quantity arsenic were present, and whether or not the public health be in any way affected. In one hundred samples taken at random, including all colors, styles, figures, and prices, twenty-four were found free from arsenic, while the remainder contained arsenic (estimated as As_2O_3) in proportions varying from a trace to 600 mgs. per square meter of paper.

It was found that it was impossible to tell from the appearance whether a paper contained arsenic or not From several thousand samples sold to pay duty at the custom house, twelve picked out at random showed arsenic in every case, ranging, however, quite low, from two to six mg. These samples were, presumably of German manufacture. The uniformity of the amount of arsenic in these papers would seem to indicate that it had been used as an antiseptic in the paste with which the pigment was applied to the paper. One sample contains an average of about 600 mg. per square meter, the arsenic being almost entirely in the red, a square meter of which, therefore, contains over one grain of arsenious oxide, while another specimen looks like the same paper, although it contains only about 50 mg.; however, it is difficult to get a fair sample of a pattern containing figures so large and varied.

There is scarcely room for difference of opinion as to the injurious effects of large amounts of arsenic in wall paper upon those who are exposed to its influence. There is little doubt that the air in rooms papered with arsenical wall paper becomes contaminated with arseniureted hydrogen, particularly in damp weather. This gas is extremely poisonous, and, though in small quantities, sometimes gives rise to most alarming symptoms.

Even if this decomposition did not take place, the air of the room must be filled with arsenic dust, particularly after sweeping and dusting, and thus cause more or less irritation of the eyes, nose, mouth, and throat, similar to the symptoms of catarrh or a cold. Some of it is swallowed with the saliva, giving rise to intestinal and constitutional disturbances of a more or less serious character, as indigestion, nausea, diarrhea, general debility, nervous prostration, etc.

Numbers of cases of fatal poisoning, in this manner, are on record, as well as many others, in which the cause was discovered in time, and on the removal of which the patients recovered. The extreme difficulty of tracing to their proper source symptoms of this character must be plain to every one. How frequently we hear the diagnosis "general debility," "nervous prostration," "indigestion," etc., the symptoms resisting all treatment until, perhaps, "rest and a change of air" are prescribed, when recovery follows, the symptoms returning, however, when the patient resumes his former work and surroundings. That many of these cases are due to arsenic in the wall paper there is abundant proof; that there are thousands suffering from this cause, of which they and their physicians are totally ignorant, is a conclusion well warranted by the evidence.

Prof. Edward S. Wood gives (Report Mass. Board of Health, 1883) a list of forty-two cases of arsenical poisoning, most of which were due to wall paper. Prof. Wood mentions a great many other articles in which arsenic has been found; among them are the following: Dress goods, muslins, linen, artificial flowers, curtains, lambrequins, gloves, calico, cloth, boot linings, paper collars, linen collars (one collar contained 10·4 grs. of As_2O_3), hat linings, colored stockings, linings in baby carriages, bed hangings, colored wax candles, confectionery, etc.

The presence of arsenic is so widespread that perhaps it would be impossible to exclude it entirely from such articles, but the deliberate use of it as a coloring for such purposes should not be tolerated. An attempt was made in Massachusetts a few years ago to secure the enactment of laws on the subject, placing the limit of arsenic in wall paper at 7 mg. to each square meter; but the wall paper manufacturers were too influential with the legislators, and the bill failed to become a law.

There is no excuse for the presence of such quantities of arsenic in wall papers, as all the colors produced by it can be made by other means, and in view of the helplessness of the average individual in the presence of such an insidious poison, its use as a pigment in all cases should be prohibited by stringent laws.—*Pharmaceutical Era.*

A New Catalogue of Valuable Papers

Contained in SCIENTIFIC AMERICAN SUPPLEMENT during the past ten years, sent *free of charge* to any address. MUNN & CO., 361 Broadway, New York.

THE SCIENTIFIC AMERICAN Architects and Builders Edition.

$2.50 a Year. Single Copies, 25 cts.

This is a Special Edition of the SCIENTIFIC AMERICAN, issued monthly—on the first day of the month. Each number contains about forty large quarto pages, equal to about two hundred ordinary book pages, forming, practically, a large and splendid **Magazine of Architecture,** richly adorned with *elegant plates in colors* and with fine engravings, illustrating the most interesting examples of modern Architectural Construction and allied subjects.

A special feature is the presentation in each number of a variety of the latest and best plans for private residences, city and country, including those of very moderate cost as well as the more expensive. Drawings in perspective and in color are given, together with full Plans, Specifications, Costs, Bills of Estimate, and Sheets of Details.

No other building paper contains so many plans, details, and specifications regularly presented as the SCIENTIFIC AMERICAN. Hundreds of dwellings have already been erected on the various plans we have issued during the past year, and many others are in process of construction.

Architects, Builders, and Owners will find this work valuable in furnishing fresh and useful suggestions. All who contemplate building or improving homes, or erecting structures of any kind, have before them in this work an almost *endless series of the latest and best examples* from which to make selections, thus saving time and money.

Many other subjects, including Sewerage, Piping, Lighting, Warming, Ventilating, Decorating, Laying out of Grounds, etc., are illustrated. An extensive Compendium of Manufacturers' Announcements is also given, in which the most reliable and approved Building Materials, Goods, Machines, Tools, and Appliances are described and illustrated, with addresses of the makers, etc.

The fullness, richness, cheapness, and convenience of this work have won for it the **Largest Circulation** of any Architectural publication in the world.

A Catalogue of valuable books on Architecture, Building, Carpentry, Masonry, Heating, Warming, Lighting, Ventilation, and all branches of industry pertaining to the art of Building, is supplied free of charge, sent to any address.

MUNN & CO., Publishers,
361 Broadway, New York.

Building Plans and Specifications.

In connection with the publication of the BUILDING EDITION of the SCIENTIFIC AMERICAN, Messrs. Munn & Co. furnish plans and specifications for buildings of every kind, including Churches, Schools, Stores, Dwellings, Carriage Houses, Barns, etc.

In this work they are assisted by able and experienced architects. Full plans, details, and specifications for the various buildings illustrated in this paper can be supplied.

Those who contemplate building, or who wish to alter, improve, extend, or add to existing buildings, whether wings, porches, bay windows, or attic rooms, are invited to communicate with the undersigned. Our work extends to all parts of the country. Estimates, plans, and drawings promptly prepared. Terms moderate. Address

MUNN & CO., 361 BROADWAY, NEW YORK.

THE
Scientific American Supplement.

PUBLISHED WEEKLY.

Terms of Subscription, $5 a year.

Sent by mail, postage prepaid, to subscribers in any part of the United States or Canada. Six dollars a year, sent, prepaid, to any foreign country.

All the back numbers of THE SUPPLEMENT, from the commencement, January 1, 1876, can be had. Price, 10 cents each.

All the back volumes of THE SUPPLEMENT can likewise be supplied. Two volumes are issued yearly. Price of each volume, $2.50 stitched in paper, or $3.50 bound in stiff covers.

COMBINED RATES.—One copy of SCIENTIFIC AMERICAN and one copy of SCIENTIFIC AMERICAN SUPPLEMENT, one year, postpaid, $7.00.

A liberal discount to booksellers, news agents, and canvassers.

MUNN & CO., Publishers,
361 Broadway, New York, N. Y.

TABLE OF CONTENTS.

PAGE

I. ARCHÆOLOGY.—Discoveries in Egypt.—A newly discovered ancient Egyptian city of the days of Rameses the Great, a graphic review of the articles of daily life exhumed by the explorer Mr. FLINDERS PETRIE, as exhibited in London 11524

II. BOTANICAL SCIENCE.—Bracket Ferns.—Some ferns valuable for growth on wall brackets for decoration of the fernery, with rules for their cultivation.—1 illustration..... 11524

Some Physiological Traits of the Solid-Stemmed Grasses, and Especially of Indian Corn (Maize).—By F. L. STEWART.—A most interesting and valuable contribution to physiological botany, the development of sugar in the stalk of solid grasses, and its sudden disappearance as the grain hardens..... 11534

III. CHEMISTRY.—A Simple Urometer.—By Prof. L. E. SAYRE.—An extemporized, home-made apparatus for the determination of urea, giving results of great accuracy.—1 illustration..... 11534

IV. ELECTRICAL ENGINEERING.—Electric Windlass and Cranes at the Paris Exhibition.—A description of these important exhibits.—Cranes of great portability for the rapid hoisting and transfer of heavy parcels.—6 illustrations..... 11522

V. GEOGRAPHY AND STATISTICS.—Pavilion of the Republic of Salvador.—An interesting building of the Paris exhibition, the use of antique Mexican symbols in its decoration.—1 illustration. 11517

Pavilion of the United States of Venezuela at the Paris Exposition.—Abstract of the history and physical geography of the South American republic, with leading statistics for 1886. Its pavilion in Spanish Renaissance, with some notes of the interesting exhibits contained within it.—1 illustration..... 11515

The Argentine Republic at the Exposition.—A lengthy abstract of the condition, industries, finances, and general statistics of this country, an article of much value and authority.—The pavilion erected by the republic at the exhibition.—1 illustration.... 11516

The Colony of Victoria.—The wonderful development of this Australian colony.—Melbourne in 1837 and 1889.—Its soil and climate.—Statistics and full details of the prospects of the country, as well as of its present status.—The Melbourne exhibition and prominent buildings.—6 illustrations..... 11511

VI. MECHANICAL ENGINEERING.—Improved Steam Hammer at the Paris Exhibition.—A hammer having its frame and base plate each pressed out of a single piece of steel, without weld or joint.—1 illustration..... 11529

VII. MEDICINE AND HYGIENE.—Arsenic in Wall Paper.—A review of the arsenic question.—The widespread use of this poison.—Dr. D. H. Galloway's recent examinations of wall papers.—Suggested legislation..... 11526

Bromoform in Whooping Cough.—A new treatment for this complaint.—Dr. Stepp's recent trials of bromoform, the dose administered, and the sensitiveness of the system to its action..... 11526

VIII. METALLURGY.—On the Hardening and Tempering of Steel.—By Professor W. C. ROBERTS-AUSTEN.—An important contribution to metallurgical science.—An examination of the theory of this little understood matter.—The archæology, history, and modern aspect of the subject.—A British A. A. S. lecture..... 11530

IX. MILITARY ENGINEERING AND TACTICS.—The Army of Kukuanaland.—By OTHO ERNEST MICHAELIS, Ph.D., U.S A.—A fanciful picture of the perfect army, details of its weapons, discipline, drill, artillery, uniform, and all other details..... 11513

X. PHYSICS.—Hysteresis.—Some interesting experiments on molecular fatigue.—The time required by a stretched wire to return to its orignal length..... 11535

XI. TECHNOLOGY.—Experiments upon the Transmission of Power by Compressed Air in Paris (Popp's System).—By ALEXANDER B. W. KENNEDY, F.R.S.—The great mechanical success attained by this system in Paris.—An exhaustive mathematical and mechanical investigation of its theory and practice, with discussion of engine indicator curves.—5 illustrations..... 11516

Useful Engineering Books

Manufacturers, Agriculturists, Chemists, Engineers, Mechanics, Builders, men of leisure, and professional men, of all classes, need good books in the line of their respective callings. Our post office department permits the transmission of books through the mails at very small cost. A comprehensive catalogue of useful books by different authors, on more than fifty different subjects, has recently been published, for free circulation, at the office of this paper. Subjects classified with names of author. Persons desiring a copy have only to ask for it, and it will be mailed to them. Address,

MUNN & CO., 361 Broadway, New York.

PATENTS.

In connection with the **Scientific American,** Messrs. MUNN & CO. are solicitors of American and Foreign Patents, have had 42 years' experience, and now have the largest establishment in the world. Patents are obtained on the best terms.

A special notice is made in the **Scientific American** of all inventions patented through this Agency, with the name and residence of the Patentee. By the immense circulation thus given, public attention is directed to the merits of the new patent, and sales or introduction often easily effected.

Any person who has made a new discovery or invention can ascertain, free of charge, whether a patent can probably be obtained, by writing to MUNN & CO.

We also send free our Hand Book about the Patent Laws, Patents, Caveats, Trade Marks, their costs and how procured. Address

MUNN & CO.,
361 Broadway, New York.

Branch Office, 622 and 624 F St., Washington, D. C.